MODERN DESTRUCTOR PRACTICE.

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"SMALL DESTRUCTORS FOR INSTITUTIONAL AND TRADE WASTE,"
"THE ECONOMIC DISPOSAL OF TOWN'S REFUSE,"
ETC., ETC.

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This work is Dedicated

TO

THOSE LONG-SUFFERING RATEPAYERS THE WORLD OVER,

OF WHOM IT WAS WRITTEN:

"We scratch not our pates,
Nor repine at the rates
Our superiors impose on our living,
But do frankly submit,
Knowing they have more wit
In demanding, than we have in giving."

PREFACE.

In the populous centres of every civilised country the problem of sanitary refuse disposal is present in a more or less acute form, and, coincidently with the ever-increasing demand for sanitary efficiency, the interest in final and sanitary refuse disposal is extending rapidly.

This work, which is primarily intended as a review of modern practice in refuse disposal, has been undertaken by the author at the request of many engineers, both at home and abroad.

An experience of nearly twenty years in combustion engineering, and an intimate knowledge of the many problems which have had to be faced in the evolution of the modern Refuse Destructor during the past eighteen years, makes it necessary for the author to express some very definite opinions, and to discuss much which is of a controversial nature.

Eight years ago, the author was responsible for a work[1] which fully discussed the position at that time; during the past seven years, however, very rapid progress has been made, and many improvements have been introduced.

The remarkable developments with British Destructors in the United States, the evolution of the German Destructor, and much progress in Continental countries and in British Colonies, are but typical of much that has been accomplished during this comparatively short period.

To one who has been closely identified with the development of some of the most valuable features in the design of the modern destructor for many years past, it is of special interest to be able to place on record the proved superiority of the British Destructor in many countries, and under difficult and widely varying conditions.

[1] *Refuse Disposal and Power Production*, published by Messrs A. Constable & Co., Ltd., London.

To many engineers, both at home and abroad, who have very kindly placed at the disposal of the author much data and many illustrations, he desires to tender his sincere thanks.

Every care has been taken to include authentic figures only, but it is possible in the arrangement of many tables and much data that mistakes have arisen. Should any inaccurate figures be detected, the author would be pleased to have the same brought under his notice for future correction.

W. FRANCIS GOODRICH.

MONMOUTH LODGE, WATFORD.

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CHAPTER I.

SOME ALTERNATIVE METHODS OF REFUSE DISPOSAL.

JUDGING by the attitude of the Local Government Board towards local authorities seeking application for sanction to obtain loans for refuse-disposal purposes, it is perfectly clear that this Government department have but little sympathy with any method of disposal other than by the provision of refuse destructors.

The following extract from the *Weston-super-Mare Gazette*, dated September 17, 1910, illustrates the attitude of the Local Government Board:—

"LOCAL GOVERNMENT BOARD'S DECISION.

"NO SANCTION TO LOAN UNTIL REFUSE DESTRUCTOR PROVIDED.

"At a meeting of the works committee held on the 12th inst., a letter was read from the Local Government Board stating that they proposed to defer their decision in the matter of the council's application for sanction to borrow sums amounting to £2365 for the provision of additional shelters on the Marine Parade and the extension of the public convenience opposite Richmond Street, *until the question of the provision by the district council of a refuse destructor* and of a new abattoir had been settled."

What are the alternative methods of refuse disposal? Briefly, they may be described as tipping on land, tipping at sea, and the pulverising and conversion of refuse into manure.

It will be observed that the Local Government Board ignore these alternatives, and specify the provision of a refuse destructor; and the Weston-super-Mare Council is not by any means the first or only council to receive such advice from the Local Government Board.

The sanitarian will note with interest that the Local Government

Board attach far more importance to sanitation in connection with a health resort than the provision of shelters on the Parade; and, unwelcome and disappointing as their attitude may be to the Weston-super-Mare Council, it will appear to every thinking person as perfectly logical and correct.

For many years past the refuse of this well-known seaside resort has been tipped on land; and while the council have done much to attract visitors, they have consistently neglected to provide for the final and sanitary disposal of their refuse.

Although Weston-super-Mare has been singled out for rebuke by the Local Government Board, it is but one of a great number of so-called health resorts in Great Britain which are concerned with all manner of improvements other than sanitary ones, and many of them will continue to pursue this course until they find themselves in the same position as Weston-super-Mare.

At many of our so-called seaside resorts it is wise to restrict one's perambulations to the Parade and the centre of the town, for on the outskirts many a beauty spot is marred by the presence of the accumulated decomposing refuse of years. An evil, unsightly mass will be found in a field by the roadside—here is the town tip. It may comprise hundreds of tons, or it may be thousands of tons, of foul-smelling, putrefying waste. Do not blame the town surveyor; it is not a monument which he has erected with any pride or satisfaction. He has reported thereon maybe a score of times to the council, and has prepared schemes providing for final and sanitary disposal, sometimes at less cost, but the council prefer their "monument of municipal wisdom."

A long and extensive experience of councils, both from within and without, has convinced the author that, as a general rule, they know little and care less about sanitation. Property owners, who are found on every council, too often resist expenditure for selfish personal ends, and in seaside and health resorts their efforts are directed towards the provision of so-called attractions, which, while involving expenditure, bring grist to the mill, inasmuch as those who own property are those who gain by an influx of population and visitors.

Having in mind that the tipping of refuse has been condemned again and again by the Local Government Board, and by medical officers of health from Land's End to John o' Groats, it is deplorable to find hundreds of local authorities still persisting in this insanitary method of disposal.

At a recent Local Government Board inquiry in a well-known and prosperous Yorkshire town for sanction to borrow the sum of £1150 for the purchase of land for a refuse tip, one of the interesting arguments

advanced in favour of the council's application was that the tip in question "would meet all requirements for one hundred and fifteen years." The fact that this same council were being urged to provide a refuse destructor appeared to possess no interest at all for them; so enamoured of an insanitary system were they that they did their best to make certain that it should be the system for another century.

The following extracts from the press afford interesting testimony as to the evils of accumulating refuse:—

South Wales Daily News, October 19, 1910:—

"PLAYING ABOUT REFUSE TIPS.

"NEWPORT PRECAUTIONS.

"At a meeting of the Newport *Health* Committee yesterday the question of disease being spread through children playing about the refuse tips was discussed. The town's refuse is deposited at St Julians and Crindau, and about twelve months ago the sanitary committee recommended the council to purchase a refuse destructor. The council did not accept the recommendation, and at yesterday's meeting *it was decided to place men near the tips to keep the children away*. Meanwhile the committee are unanimously of opinion that a destructor should be acquired."

South Wales Echo:—

"DEATH AT A REFUSE TIP.

"The inquest of the body of William Webbe, labourer, who died on the refuse tip in Waterloo Road, Cardiff, yesterday, was held this afternoon, when medical evidence showed that the deceased succumbed to heart disease, accelerated by the heat *and the smell from the refuse*."

The Flixton Telegraph:—

"A report was presented to the committee, showing that within a radius of 200 yards from the existing tip there had been fourteen cases of scarlet fever and eight cases of diphtheria—two of the latter proving fatal—in a period of eighteen months."

The Times, January 13, 1911:—

"THE RAT DANGER.[1]

"REFUSE TIP AT LICHFIELD.

"At a meeting of the Lichfield City Council last night, correspondence with Captain W. B. Harrison of Aldersham was read, who complained of

[1] The Lichfield Corporation have since decided to erect a destructor.

the damage done to crops by rats from the corporation refuse tip at Femley Pits. He declared that rats were in such abundance as to constitute a grave danger to the public health, and to make the continued maintenance of the corporation tip a public scandal.

"Mr H. Winterton, chairman of the sanitary committee, said the rats had become so numerous at the tip as to make it a *veritable plague spot*, and this opinion was endorsed by Drs Morgan and Welchman."

The Municipal Journal, June 1, 1906:—

"COVENTRY REFUSE TIPS—AN OBNOXIOUS METHOD.[1]

"In his annual report the medical officer of the city of Coventry, Dr E. H. Snell, calls attention to the obnoxious method of getting rid of the refuse by tipping it in huge accumulations on the confines of the city.

"Quite a number of rag pickers find employment by sorting over the heaps and bringing back into the city everything in the nature of rags which can be sold to rag dealers; the offensiveness of much of this material is not a matter of moment to them. The drainage from these accumulations is highly objectionable. It partly enters the city sewers, partly drains into the canal, and partly into other channels so situated that they receive it."

The Freeman's Journal:—

"BLACKROCK URBAN DISTRICT COUNCIL.

"DUMPING REFUSE IN THE PARK.

"A meeting of this council was held for the purpose of considering a recommendation sent up by the committee appointed to consider the *best means* of disposing of the township refuse.

"The report of the committee suggested that a wooden dam should be erected across the pond in the park at about 80 yards distant from its west end, and that the portion enclosed should be filled up to a height of about 40 feet with refuse and enclosed with a hoarding.

"It was proposed that the committee's report should be adopted. They had a lovely park, *and they should make it attractive to residents and visitors*. They should instruct the police to prevent the depositing of dead dogs, or cats, or donkeys in the park.

"Ultimately the report was adopted."

The Melbourne Argus:—

"Cows that pick up a precarious livelihood from the varied but not very nutritious resources of corporation tips not unnaturally develop a

[1] The Coventry Corporation have since erected a destructor.

taste for onions in preference to jam tins or old boots, which generally form the staple of these unsavoury heaps. Not having any particular susceptibilities on the subject of a pungent breath, the result is no doubt satisfactory to the cow, but it is not so to the milk consumer.

"At the meeting of the Port Melbourne Council last night complaint was made by several local cowkeepers who, it seems, select this sort of pasturage for their animals, that owing to the cows eating the onions so temptingly deposited on the garbage tip at Fisherman's Bend, the evening's milk for several days past had been unfit for use. They suggested the erection of a fence round the tip. In view of this disgusting disclosure, the Mayor-Councillor Hester strongly recommended the Government fencing its grazing area on the bend, as it received dues from the owners of cattle grazing there. Councillor Armstrong said he had seen the tip that day, and it was in a most disgraceful condition. It was shocking to think that householders should have to consume milk tainted in such a manner."

The foregoing are but a few out of many extraordinary reports concerning the tipping of refuse; comment thereon is unnecessary.

In the tipping of refuse many municipal authorities show an utter disregard for the consequences, and there is a growing tendency to inflict the refuse on other communities foolish enough to permit the same to be deposited within their area.

Many of the London boroughs thus get rid of their refuse through contractors, twenty and even thirty miles out of the Metropolis; the foul miasma arising from vast heaps of London refuse pollutes the atmosphere of the countryside, and on more than one occasion has been the subject of litigation.

Commenting upon the decision of the borough of Richmond, Surrey, to thus get rid of their refuse, the following editorial notes from *The Surveyor* are of interest:—

"The existing state of affairs is, then, that Richmond is to rid itself of its house refuse by dumping it, in all its pristine vigour of aroma, within the confines of other districts. Upon what community it may be inflicted is a detail which concerns Richmond least of all, and whether their contractor scatters his 8000 tons of miscellaneous filth broadcast over the surface of the country, whether he dumps it in one gigantic heap in some adjoining district, or whether he dispenses his favours by depositing it on the instalment system in a number of districts, is, to Richmond, one and the same thing. In eight years much may happen, including sporadic outbreaks of zymotic disease arising from the dumped deposits from the borough of Richmond. . . . However, it is only for

eight years, and perhaps ere that period has flown communities will be forced by legal enactment to dispose of their own refuse, and no longer be allowed to resort to the objectionable and injurious practice of tipping."

One of the most objectionable and dangerous features of refuse tipping is the fly pest. It is common knowledge that the common fly multiplies at an alarming rate, and those who are at all familiar with

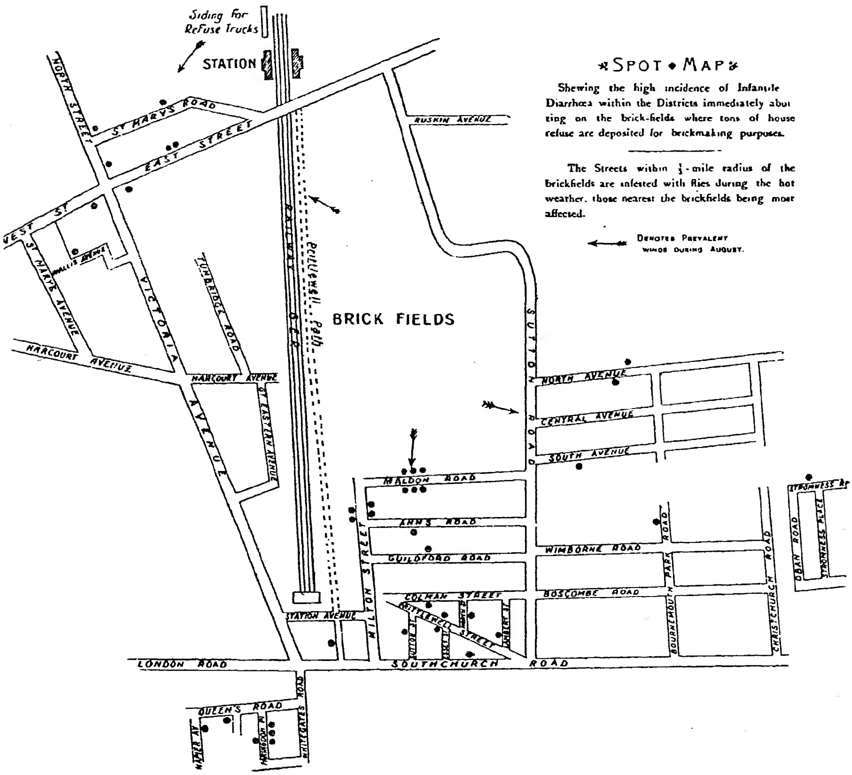

Fig. 1.—Spot Map, Southend-on-Sea.

refuse tipping will be well aware that myriads of flies are found on refuse heaps.

Some few years since Dr Nash, the present county medical officer of health for Norfolk, who at the time in question was medical officer of health for the borough of Southend-on-Sea, was much concerned with the rate of mortality in houses adjacent to the refuse tips, and, after much patient investigation, he came to the conclusion that the trouble was due to the contamination of food by flies from the refuse tips entering the open windows of the adjacent houses.

The spot map, fig. 1, was prepared by Dr Nash; each spot indicates a house where a death occurred during a comparatively short period, the deaths being attributed by Dr Nash to the fly trouble.

The following extract from the *Daily Mail*, dated June 3, 1911, affords ample confirmation of the opinion of those medical men who have long contended that flies from refuse tips are responsible for the spreading of disease. This is especially interesting at a time when there is a tendency to disregard the opinion of many eminent medical officers of health.

"The plague of flies at Postwick, near Norwich, last summer was

FIG. 2.—East London—a Refuse Tip, now converted into a recreation ground.

shown by experiments to be due to the presence of a large heap of refuse about half a mile away.

"Some of the flies travelled (according to a *Local Government Report* issued yesterday) 1700 yards, crossing the river Yare and a hill. Experiments show that infected flies, both house-flies and blow-flies, are capable of infecting fluids such as milk and syrup, on which they feed and into which they fall."

Fig. 2 illustrates a refuse tip in East London which was, until recently, the daily resort of a considerable number of children, who carefully sorted the material and extracted therefrom various articles, which were sold. Owing to the personal interest and suggestions of the president of the Local Government Board, the Right Hon. John

Burns, M.P., the tipping of refuse has ceased, and the land has been converted into a public park.

At a Local Government Board inquiry at Newtown, Montgomery, on April 22, 1909, concerning the application of the council for sanction to borrow £600 for the provision of a refuse destructor, the medical officer of health, when giving evidence in support of the council's proposals, made the following observations:—

"The present tip bred flies which carried infection; it was near to about 100 houses, and was infested with rats, which forced their way into the adjoining cemetery."

In his annual report for 1909 the medical officer of health for Droylsden said: "the tipping of refuse is most objectionable; and not only is it a nuisance to the inhabitants, but it is becoming a source of danger to the public health."[1]

So much for tipping on land, a system which would come to a speedy end if those who represent the public could only be brought to realise that their first and foremost consideration must be the public health.

DISPOSAL AT SEA.

The tipping of refuse at sea is a method of disposal which has never made much headway in England, and is being gradually abandoned.

The Local Government Board have shown, in connection with more than one loan application for refuse barges, that they are no more satisfied with the tipping of refuse into water than depositing it on the land.

Some few years since, the Teignmouth Urban District Council having made application to the Local Government Board for sanction to borrow the sum of £600 for the provision of a refuse barge, were requested to furnish the board with (1) a plan of the barge, and (2) a guarantee that none of the refuse would come back on the shore. The Teignmouth Council withdrew their application.

The Corporation of Plymouth used a hopper barge having a capacity of 190 tons for some time, the cost of disposal being 1s. 7d. per ton. Owing to serious accumulations of refuse at the depôt during rough weather, and complaints concerning the fouling of the fishing grounds with refuse dumped at sea, this method of disposal was abandoned in favour of a destructor.

Recently, in connection with towns on the Pacific seaboard of the United States, it has been decided that all refuse dumped at sea must be deposited at least twenty miles out.

For many years the Department of Street Cleaning of the city of

[1] The Droylsden Urban District Council have since erected a destructor.

New York sent vast quantities of rubbish out to sea; the filthy condition of beaches owing to the drifting back of a great deal of miscellaneous waste, followed by continual and serious complaints, led to the abandonment of this method of disposal.

For some years the Corporation of Dover dumped the refuse of that town some three miles out in the Channel. Fig. 3 is a view of one of the Dover Corporation refuse barges. The following is an extract from *The Dover Express,* dated January 14, 1905:—

"Councillor W. Bradley said there was another matter he wished to

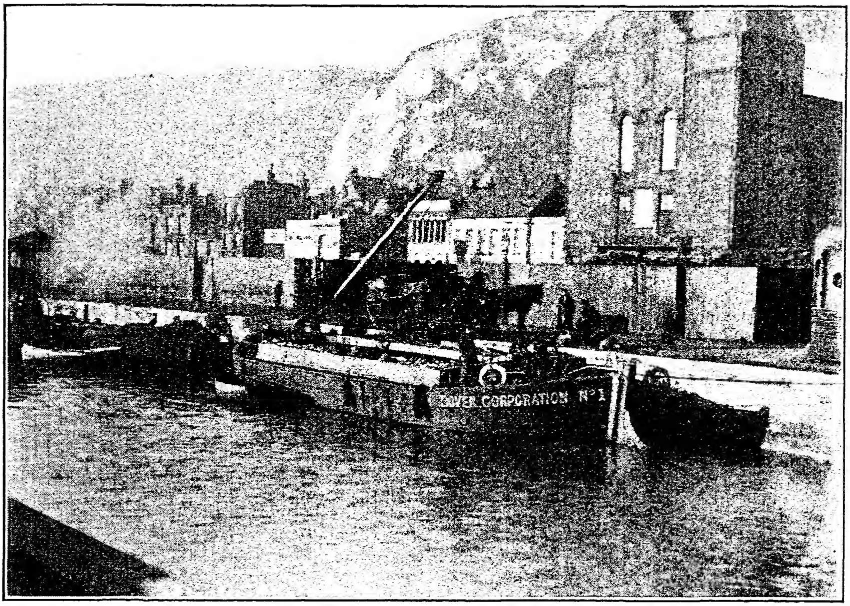

Fig. 3.—Refuse Barge (Dover Corporation).

refer to in the presence of the medical officer. He had received more than one complaint since the scavenging barge had been placed in the corner of the pent, near the junction of Northampton Street and Commercial Quay. *The barge lay there for days, and a very objectionable stench arose from it,* to the detriment of the inhabitants in the immediate neighbourhood. He asked that it should be taken to some other part of the harbour, not so near dwelling-houses. Alderman Bussey said that, until recently, it had been kept at the top end of the pent, which was even more objectionable.

"The medical officer said it was fifteen years since he recommended a

destructor; there was one at Leeds, where he came from, and one at Folkestone. He thought Dover very behindhand in not having a destructor; 'it is one of the most important things you want.'"

In 1907 the Corporation of Aberavon found it a very difficult matter to convince the Swansea Corporation that the refuse barged out to sea from Swansea was being washed up on the Aberavon beach. In order to definitely settle the question, the sanitary inspector of Aberavon went out to sea in one of the Swansea barges and deposited coke in wire netting and sealed receptacles which were then thrown overboard with the refuse. During the high tides which subsequently prevailed the beach at Aberavon was strewn with the black refuse. Between the two piers, and for two miles below the north pier, the sands were covered with ashes and other rubbish, among which were discovered some of the sealed packages which had been dropped out at sea.

The Corporation of Liverpool still send some of their refuse to sea; during 1909 the "Beta" thus disposed of 28,558 tons. During the twenty-six years this barge has been in service 5200 trips have been made, the total mileage being 281,200, and no less than 1,852,000 tons of Liverpool refuse have been dumped at sea.

The "Beta" has a hopper capacity of 380 tons, and all refuse is dumped one mile or so beyond the N.W. lightship. It should be noted that while the Liverpool Corporation disposed of 28,528 tons of refuse at sea during 1909, no less than 206,000 tons were destroyed in their six refuse destructors.

While sea disposal, as conducted at Liverpool, cannot be termed unsatisfactory, the fact remains that in almost every other place where it has been tried it has been proved to be very unsatisfactory. The troublesome features have been (1) the nuisance in the barge or at the depôt while the refuse is being accumulated to make up a cargo. (2) The nuisance—occasionally very serious—due to inclement weather and consequent delay in proceeding to sea. (3) The washing up of quantities of refuse on beaches, in some cases a considerable distance from the point at which the material is dumped.

REFUSE PULVERISING FOR MANURIAL PURPOSES.

Although introduced in this country some years ago, this method of disposal has generally failed to carry conviction as a system which is a satisfactory alternative to disposal by fire. At this time, after exploitation for some years in France, it is found that provision must be made for burning either some portions of the refuse all the time, or for burning

the whole of the refuse at such times as the demand for the manure falls off, and it is upon such lines, with combined destructor and pulveriser works, that the important French company, the *Société Générale des Engrais Organiques*, is now operating. In London the "Lightning dust manipulator" was adopted by the Metropolitan borough of Southwark in 1906. This apparatus, which was first known as the "Clero" crusher, was originally designed for the pulverising of minerals, and consists of a strong cast-iron box, in which rapidly revolving hammers are contained. The refuse is shovelled into a hopper, and falls under the hammers and against the breaking block. The breaking up of the material takes place between the hammers and the breaking block, the friction of the parts while in suspension assisting the disintegration. The final pulverisation is effected by trituration between the hammers and some of the lining plates.

The main features of the machine are the special alloy steel horizontal swing hammers, connected at their extremities with two parallel heavy discs, which act as flywheels, and turn with the shaft to which they are keyed at a speed of from 1000 to 1200 revolutions per minute.

That the refuse is well pulverised is beyond question, but there are a number of points which demand consideration in connection with such a method of disposal.

The cost of the Southwark installation as originally designed was £2190, which sum included the pulverisers, motors, conveyors, and the buildings, the capacity of the plant being 40 tons daily.

The working cost as given by Mr A. Harrison, the borough engineer of Southwark, is as follows:

Electric power at one penny per unit	8 pence per ton.
Labour	13 " " "
Beaters, grids, and repairs . .	3 " " "
Oil and sundries	1 penny " "
Total	2s. 1d. per ton.

It will be observed that the consumption of current per ton of refuse pulverised is 8 Board of Trade units, while the price per unit is low; the labour figure is high, and would be a good average, if not rather above the average, for a refuse destructor, while the cost of beaters, grids, and repairs is a serious item.

The above figures appear to be the average during the first eighteen months' operation, during which time 10,802 tons of pulverised refuse manure were sold at an average price of 2s. 4d. per ton, out of which 1s. 9d. per ton had to be paid for carriage, thus leaving 7d. per ton net

revenue to set against the operation cost of 2s. 1d. per ton, excluding the capital charges.

Mr Harrison estimates that 5 per cent. of the material received at the Southwark Works is too large for the machines and has to be disposed of otherwise.

It is very important that disused floor covering, mattresses, bedding, and large carcases should be finally disposed of; and while such are being disposed of daily in refuse destructors, it would seem that they cannot be dealt with in the pulveriser.

In considering the adoption of the pulveriser system it is obvious that one of the most important points to be decided is whether or not the manure can be disposed of, not for a limited period, nor for a few months each year, but constantly and always. Is its composition such that it is suitable or beneficial for any soil? Is its composition fixed or does it vary? For it must be borne in mind that there are many artificial manures on the market of known and unvarying composition and proved value.

Another important point is, Where can it be sold? The figures already quoted in connection with the Southwark sales indicate that the cost of carriage, even for a comparatively short distance, may be such as to leave but a small margin; and if the market has to be found at a distance, then the sale price must be such as will cover the cost of carriage, or the transaction must obviously be an unprofitable one.

The following report prepared for the Corporation of Chester by Mr T. J. Young, of the Holmes Chapel College, and Mr S. E. Britton, the borough electrical engineer of Chester, discusses the analysis, etc., of pulverised refuse from the Southwark Works.

The *Chester Courant*, December 28, 1910:—

"The Chester Town Council minutes just issued disclose a fresh outburst of activity by the refuse destructor committee. A deputation recently was appointed to visit the refuse crushers installed at Southwark, while Mr T. J. Young, Principal of the Holmes Chapel College, was engaged to make a formal analysis and report upon a sample of crushed refuse from Southwark, and a sample of sewage sludge from the sewage disposal works, Chester. Mr Young reported as follows:—

"Samples Nos. 1 and 2—sludge—although they would have, as shown by analysis, a beneficial effect on land, yet, by reason of their physical state, they would probably be very difficult to mix with the soil so as to become incorporated with it in a desirable way.

"Samples Nos. 3 and 4 - destructor refuse—are in a good physical

condition, and thus are better adapted for application to land than the two sludges. Their chief fertilising value would be as a slow acting source of nitrogen, but the lime and phosphate present would also be useful. The refuse is a type of fertiliser which would recommend itself for fruit-growing or other horticultural work of similar character. It would also appear to be suitable for permanent grass land for working in with the chain harrow, provided a rapid action of the nitrogenous constituent was not required. . . . Both materials would, in ordinary circumstances, be more suitable for heavy land than light, so far as fertilising constituents are concerned."

In connection with the same matter Mr S. E. Britton, electrical engineer, reported as follows:—

"The cost of a complete pulverising installation ready for use would be £2500. The annual cost of pulverising 12,500 tons of refuse delivered direct from the crushers into carts or trucks at the depôt would be £1500, which sum includes capital charges, power, repairs, and labour, *i.e.* 2s. 5d. per ton. From this may be deducted the saving in cartage, labour at tip, and sale of metal, together amounting to £670, leaving a debit balance of £830, reducing the 2s. 5d. per ton to 1s. 4d. per ton. In other words, unless a perpetual sale of this disintegrated refuse is maintained at 1s. 4d. per ton, the process could not possibly be anything but a burden to the rates. To give it away means a penny rate; and should it be necessary to remove it to a tip or pay farmers to dispose of it, the lowest figure that could be reckoned upon would be a twopenny rate.

"In the event of the farmers entirely rejecting the refuse, a tip must be resorted to, with its adherent objections. Mr T. J. Young in his report states that 'nitrogen, the chief fertiliser, is slow in action.' It therefore seems to me that in these days, when the chief desire is to increase the yield per acre, low grades of manure will decrease in value. He also stated that 'crushed refuse would recommend itself for fruit-growing and other horticultural work.' Unfortunately the land around Chester is not used extensively for this purpose. The only other suggestion of any real value is that 'it would appear suitable for permanent grass, if rapid acting nitrogen is not required.' There certainly is plenty of pasture land round Chester, but unfortunately it would not do to put it on grass at all seasons of the year. Having regard to the opinion from expert agriculturists and the fact that crushed house refuse cannot take the place of any recognised fertiliser, it is not conceivable that farmers around Chester would for any length of time take it away without being paid to do so. The remoteness of achieving a regular sale at 1s. 4d. per ton of a substance which has little

or no manurial value has thoroughly convinced me that such a system is not advantageous; therefore, although the cremation of refuse necessitates a larger initial expenditure, I am of opinion that, both for sanitary efficiency and net cost of disposal, the wisest course to adopt for the disposal of house refuse would be a system of cremation.

"It was resolved (1) that the appointed deputation be requested to proceed to Southwark; (2) that the electrical engineer be instructed to prepare plans and specifications for the erection of a refuse destructor at and in conjunction with the sewage disposal works."

From such figures as are available, it is clear that under average circumstances, where the power can be utilised from a refuse destructor, the fuel value of the refuse will be more than the value of the refuse when converted into manure, but for purposes of comparison we will take a small destructor dealing with about 10 tons of refuse daily, where the power is not fully utilised.

At Exmouth some 3300 tons of refuse are destroyed per annum, at a labour cost of 11½d. per ton, the revenue from steam sold being £77 per annum. The cost of the destructor complete was £3000 and a twenty-seven years' loan was sanctioned, the interest and sinking fund charges being 11½d. per ton or equal to the labour cost; deducting from the total charges of 1s. 11d. per ton the revenue from the steam sold, the *inclusive cost* of destruction is 1s. 5½d. per ton, a very creditable figure.

While a pulverising plant certainly has the advantage in capital expenditure, it will be seen that various factors must receive careful consideration.

The Corporation of Chester decided to install a refuse destructor, but pulverising installations have been adopted at Halifax, Yorks, and Ross, Herefordshire, the operation of which will doubtless be watched with much interest.

The pulverising of refuse is further referred to in Chapter II., discussing foreign and colonial practice.

CHAPTER II.

REPRESENTATIVE TYPES OF BRITISH DESTRUCTORS.

SOME few years since, each of the British makers specialised in destructors of one or two types only. For instance, front feeding was the speciality of one maker, back-fed destructors were made by two firms, the top-fed type was the speciality of two makers, while only one maker offered a mechanically charged destructor.

Within recent years the position has materially changed. The ever-increasing demand for continuous-grate destructors has had the effect of stimulating the efforts of several makers in this direction; and while this type has not yet been adopted as the standard by all, it is invariably offered by most of them when it is specified.

The constant demand for shovel-fed destructors of both types, back and front, has compelled destructor makers to offer this type. Those who have been prominently identified with the continuous-grate destructor have also developed this type for both top and mechanical charging, realising that both systems of charging are much more efficient with a continuous grate than with isolated cells.

Before discussing and illustrating the various types of destructors, it may be well to consider the relative advantages of the cellular or isolated-cell system and the continuous-grate system.

The "Cellular" System.—The "cellular" type of destructor dates back to the original Fryer patent of 1876. Destructors of this type comprise two or more cells, arranged either in a single row or back to back, each cell being completely isolated from the adjoining cell or cells.

Instead of being provided with a combustion chamber as distinct from the main flue, a main flue only is provided, and it is at this point that the gases from the various cells commingle.

The essential weakness of this design is found in the fact that there is no "mutual assistance" *within the furnaces.* One cell is discharging hot gases under the boiler or into the main flue, while the adjoining cell

is cool and inactive, low temperature and objectionable gases meanwhile passing into contact with the boiler or into the main flue, and there reducing the temperature of the whole.

During the clinkering and charging of a single cell, cold air passing into the cell quickly lowers the temperature, and having direct access to the boiler or main flue, the effect here in reducing the temperature and working efficiency is serious. Again, it should be borne in mind that when unburned gases once reach the chimney it is absolutely impossible to prevent nuisance.

It has been frequently claimed for the isolated or cellular system that a cell may be put out of service and repaired while the adjoining cell or cells are in operation. If anything like a reasonably high temperature is maintained this would appear to be impossible; it is well known that under high temperature conditions the firebrick lining of a cell is red hot for at least 6 inches in depth.

If repairs can be carried out in a single cell adjoining a cell in operation, it is obvious that the normal temperature must be too low for efficient working.

Owing to the greater surface of exposed firebrick in isolated cells, the repairs are the more frequent and costly; the outlet flues are often small, and there is a tendency for them to become partially choked, which has the result of causing back draught; the higher the temperature the more troublesome this difficulty becomes.

During the past ten years comparatively few cellular destructors have been erected. For every destructor of this type which has been built during this period, at least five destructors of the continuous-grate type have been erected. There could be no more conclusive proof of the all-round superiority of the continuous-grate type than the fact that this type is now offered by every destructor maker in England with but a single exception. In America it is the standard British type, and in continental and tropical countries it is generally recognised as of vital importance.

The Continuous Grate.—Briefly described, the continuous grate has, as its essentials, the provision of a common furnace chamber with divided or separate ashpits (which may number from two to six according to the grate area) and a common combustion chamber.

While in actual principle the continuous grate with separate ashpits is not novel, it was not applied in connection with a regenerative high temperature refuse destructor until some fourteen years since, at Darwen.

The real step forward in modern destructor practice dates from this

time; for some years the continuous grate was ridiculed by the makers of the cellular type of destructor as possessing no real advantage excepting in the cost of construction. It was termed "a flue filled with firebars," and its adoption was made as difficult as possible by those who were interested in the isolated-cell system.

In course of time it was found that the arguments fell flat, and that it was all but impossible to convince engineers that this was not the rational type of furnace. The ever accumulating evidence in the form of working results began to tell, with the result that the continuous grate was frequently specified, and, so far as was possible, the various makers gradually fell into line.

As one who devoted much time and attention to the development of the continuous-grate system for many years, the author may perhaps be forgiven for an unusual enthusiasm. This type has in practice been proved to show a working efficiency far in advance of that previously obtained, both with the best and also the most inferior refuse.

In destroying refuse of very low calorific value, or with a high percentage of moisture, the continuous grate possesses manifest advantages over the isolated-cell system. Refuse can be efficiently burned with the former which it is very difficult, if not impossible, to burn with the latter type.

In the maintenance of a high working temperature in the furnace and combustion chamber, in the avoidance of nuisance, in power production, and in maintenance cost, it has been amply demonstrated that the continuous grate marks a great advance upon previous practice.

It is only since the introduction of this type that the power production aspect of refuse disposal has become a prominent feature. The easy maintenance of a reasonably constant steam pressure which is governed entirely by a well-maintained furnace temperature has done much to convince those who wish to use the steam that the supply is a satisfactory one.

The combustion chamber—a feature of the utmost importance—has met a long-felt want, not only in securing the complete diffusion and commingling of the gases before they reach the boiler, but also in the interception of about 75 per cent. of the dust at a point from which it can be easily removed without a stoppage.

With the cellular type the bulk of the dust is deposited in the main flue and cannot be removed until the plant is idle.

It is important to remember that the "dust catcher" was introduced with the cellular type of destructor. A separate dust catcher is but rarely used with the continuous-grate type because, as already observed,

the bulk of the dust is intercepted in the combustion chamber, and that small portion which is carried in suspension in the gases beyond the boiler is trapped in the pit underneath the regenerator.

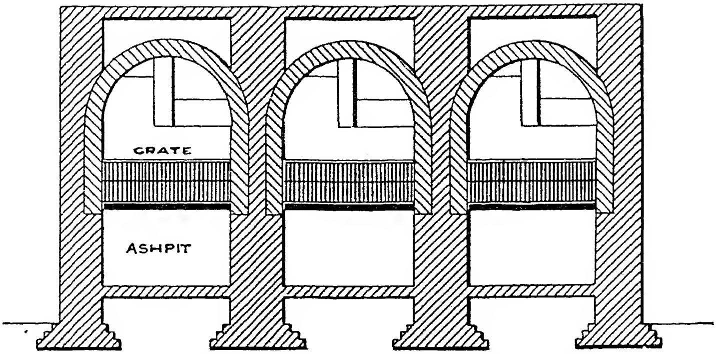

FIG. 4.—The "Cellular" Destructor. Sectional view.

Under such conditions very little dust reaches the main flue, whereas with the cellular type most of the dust is deposited at this point.

The well-maintained high temperature in the furnace and combustion chamber renders nuisance impossible, always providing that the destructor is properly operated. The maintenance cost in many cases is so low as to be scarcely credible. The records in Table XII. are worthy of careful perusal and serve to illustrate this contention.

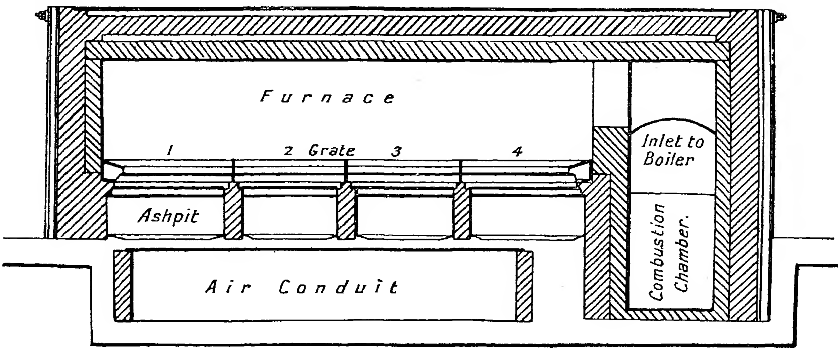

FIG. 5.—The "Continuous-Grate" Destructor. Sectional view.

In figs. 4 and 5 the two types under discussion are illustrated: fig. 4 shows three isolated cells, while in fig. 5 is shown a 4-grate destructor of the continuous-grate type, and combustion chamber. These illustrations will serve to convey the essential difference between the separate or isolated cells and the common furnace chamber with divided or separate ashpits only.

Top Feeding.—Taking the various types of British destructors approximately in the order in which they have been introduced, it is necessary to begin with the top-fed type.

Fig. 6.—The first Destructor. Erected for Manchester Corporation in 1876.

The first destructor cells of this type were erected by the late Mr Alfred Fryer in 1876 for the Corporation of Manchester, which installa-

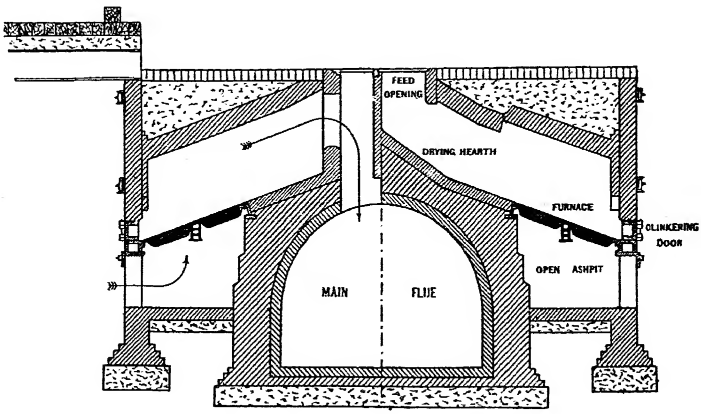

Fig. 7.—The original "Fryer" Destructor. Cross-sectional view through cells.

tion is illustrated in fig. 6. It is interesting to note that this, the first refuse destructor, is still in operation.

The arrangement of the Fryer destructor as originally designed is shown in fig. 7. The ashpits, it will be noted, are of the open type, for

working with natural or chimney draught. Some few of the old cells of this type are still in use in various parts of England.

About seven years since the original cells at Manchester were equipped with steam-jet blower forced draught; the closed ashpits and steam-jet blowers will be seen upon reference to fig. 6.

The Warner top-fed destructor, which was introduced about twenty-three years since, and has been adopted in various parts of the United Kingdom, and also in the Colonies, in common with the Fryer destructor, is of the cellular type, and is usually arranged with a multitubular boiler set between a pair of cells.

Fan-forced draught is used; and in connection with some of the more recent installations a separate fan is provided for each cell.

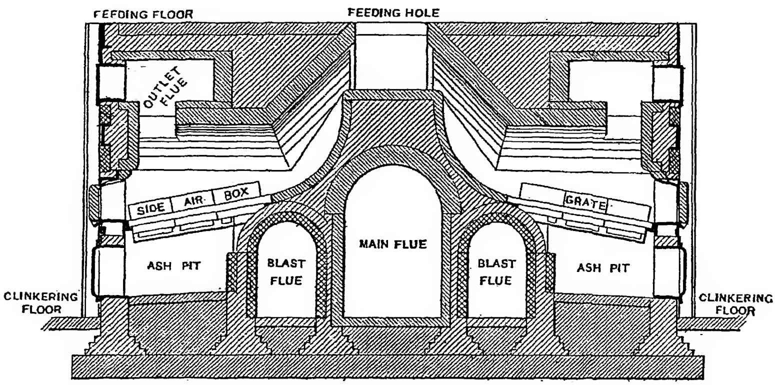

Fig. 8.—Horsfall's Top-fed Destructor. Cross-sectional view through cells.

The Horsfall top-fed destructor was introduced about 1887, and was a distinct advance upon the original type. The direction of the gases passing from the cell was changed: instead of leaving the cell at the rear, the design provided for a front exhaust, the gases from the drying hearth passing over the active fire, the entire volume of gases leaving the cell at the front and near the top. The provision of steam-jet blower forced draught was another feature of great importance. This type of destructor is illustrated in fig. 8. With the exception of detail improvements in general design, the top-fed destructor was not materially changed until 1893, when the Beaman & Deas type was introduced. The principal features of this type were the provision of a combustion chamber common to a pair of cells, the combination of a Babcock & Wilcox water-tube boiler, and the use of fan-forced draught.

The guaranteed destroying capacity of a Beaman & Deas cell was 15

tons per twenty-four hours. Introduced at a time when the destroying capacity of other top-fed cells varied from 6 to 9 tons per twenty-four hours it was regarded as revolutionary, and much interest was aroused.

Although the Beaman & Deas destructor was exceedingly successful as a destructor, unfortunately it was not a commercial success. Some seven years have now passed since the last destructor of this type was erected.

Wood & Brodie's patent, providing for the setting of a water-tube

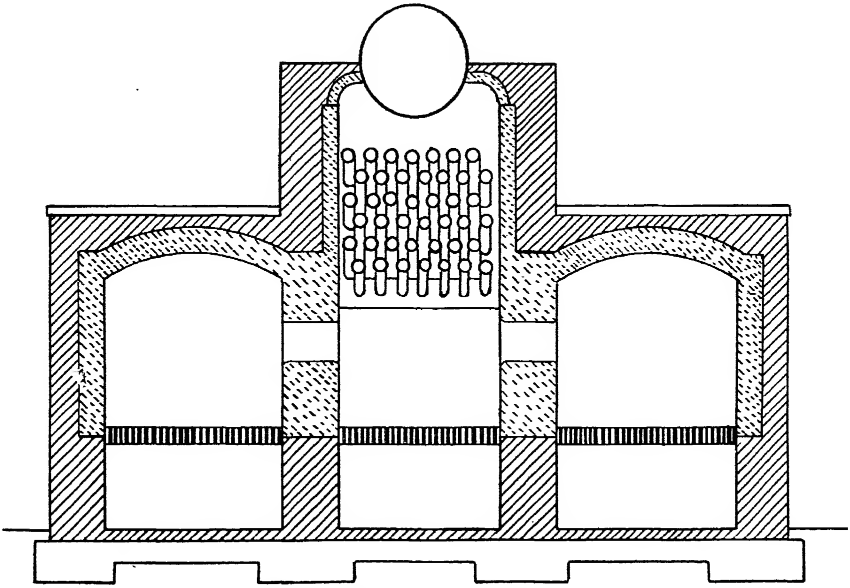

FIG. 9.—Wood & Brodie's Patent Setting. Sectional view.

boiler between a pair of top- or mechanically-fed cells, was introduced about 1893, and is illustrated in fig. 9.

It will be observed that the gases pass direct from the cells to the boiler without the provision of a combustion or dust-settling chamber. A number of destructors of this type have been adopted.

Following the introduction of the Beaman & Deas destructor, and Wood & Brodie's improved setting, the next important innovation was the use of the continuous grate in connection with top-fed destructors.

This improvement, which had the effect of completely changing the design, also involved the use of regenerators for heating the air supply for combustion.

Simultaneously with the introduction of these improvements an improved system of refuse storage was introduced. Hitherto the refuse

had been stored either directly on top of the cells or on a platform a few inches above the cells. To avoid the constant complaints due to the stewing of the refuse, and to provide better working conditions for the staff, large steel storage bins were introduced, the arrangement of which is shown in fig. 10.

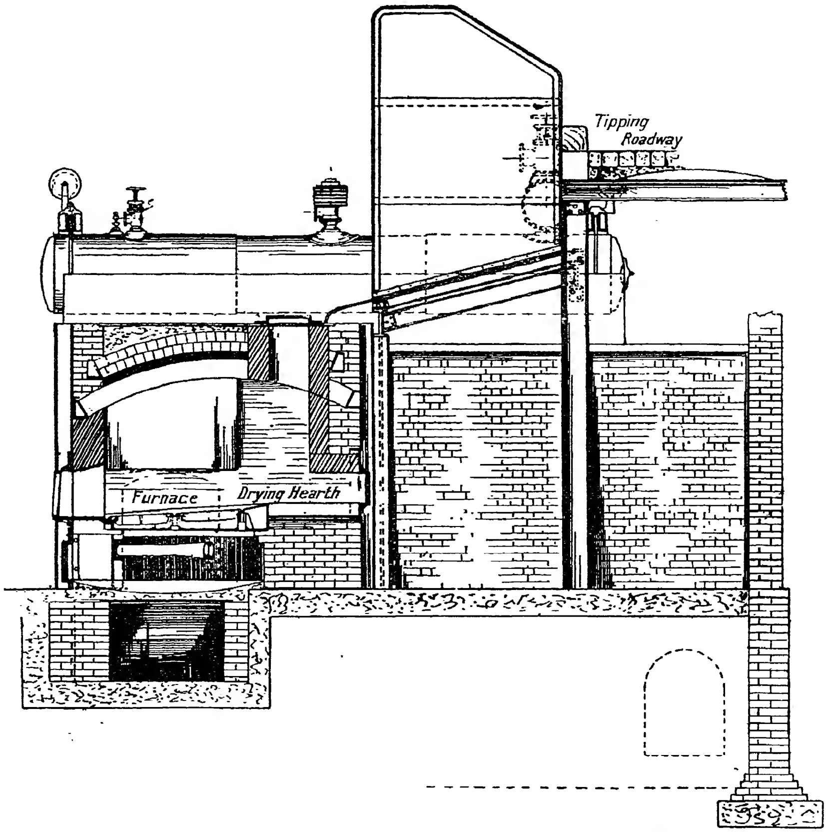

Fig. 10.—Meldrum's Top-fed Destructor. Cross-sectional view.

Destructors embodying these features were introduced by Messrs Meldrum and Messrs Heenan & Froude, Ltd., while, about the same time, the "Sterling" destructor was introduced by Messrs Hughes & Stirling. The latter, while embodying the continuous-grate principle, was arranged, as shown in fig. 11, with a central combustion chamber, the boiler, usually of the water-tube type, being set at the rear of the combustion chamber.

Although the central combustion chamber was a special feature of the "Sterling" top-fed destructor as originally designed, the position and

arrangement of the combustion chamber may, of course, be changed if desirable, and placed at either end of three, four, or more grates.

The refuse is invariably stored in closed steel bins. For the heating of the air supply for combustion a regenerator is used, either with fan or steam-jet blower forced draught.

The "Heenan" top-fed destructor embodies the continuous grate, fan-forced draught, regenerator, and cool storage of the refuse. A typical plant is illustrated in plan in fig. 12.

In connection with both the "Heenan" and the "Sterling" top-fed destructors considerable attention has been devoted to charging by means of containers arranged to deliver the refuse into the cell in fixed or measured quantities. This is a point of vital importance if the top-fed destructor is to have a future. Under the cellular system the uncon-

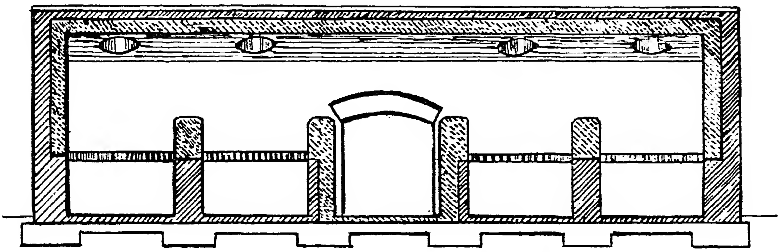

Fig. 11.—The "Sterling" Top-fed Destructor. Sectional view.

trolled charging of refuse into top-fed cells has been responsible for constant complaints concerning nuisance.

With a regenerative continuous-grate top-fed destructor, embodying a container feed, strictly limited to a comparatively small and regular charge, the top-fed plant will give such satisfaction as has not hitherto been experienced.

Mechanical Charging.—Fig. 13 illustrates the system of tank or truck storage and charging which was introduced by Messrs Boulnois, Wood & Brodie, and has been adopted in several destructor works in various parts of England.

Briefly described, this system necessitates the provision of a storage platform immediately under the tipping platform; the vehicles discharge the refuse in trucks which run on rails; the trucks are divided into compartments, each of which will contain a cartload of refuse, which represents a charge.

When it is desired to introduce a charge into a cell, the truck is moved forward into position by means of a winch which is controlled from the tipping platform, and by a simple movement the placing of the

truck in position serves to remove the cover of the charging opening, also releasing the doors at the bottom of the truck and discharging the contents on to the drying hearth beneath.

The storage provided is cool, and the whole apparatus is of a simple character and easily operated.

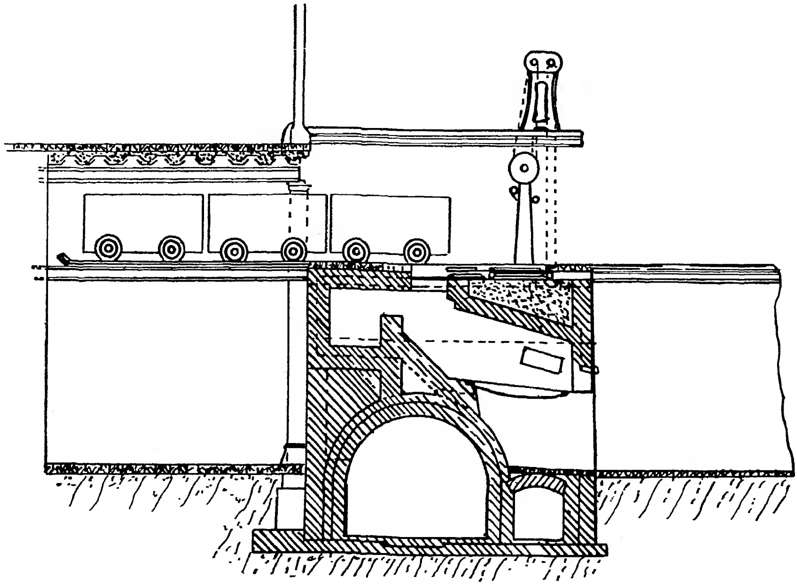

FIG. 13.—Boulnois, Wood & Brodie's Patent Truck-charging System.

Direct Cart-fed Destructors.—For the direct charging of a cart-load of refuse into a cell without handling, no less than three different types have been introduced, but neither one has been extensively adopted. The first of this type was Marten's patent direct-charging apparatus, which is illustrated in fig. 14, showing its application to a destructor of the Beaman & Deas type. This apparatus, which it will be observed is exceedingly simple in design, was adopted in connection with Beaman & Deas destructors at Wandsworth and Kingston-on-Thames. The Horsfall Destructor Company, Ltd., introduced a simple form of cart-fed destructor with an intermediate hopper, which was adopted at Blackpool and Bromley. The third of this type (Warner's) differed from those already referred to, the refuse being tipped direct into the cell without the provision of a separate top hopper. The Horsfall Company erected one plant of a somewhat similar type to this for the city of Westminster.

The main reason why so few destructors of the cart-fed type have been adopted is because, with the earlier types, the storage of the refuse

in vehicles was an essential part of the system, which, if adopted, necessitated the provision of many more vehicles than were required for the actual collection of the refuse. Further, for the backing of the vehicles, it was found necessary to keep a horse available during the night.

With the later types, which provided for storage within the cell, it was found unsatisfactory to thus store the refuse, which, owing to the heat, swelled to such an extent on the drying hearth that much labour was involved with unusually long and heavy tools in order to drag the material over the grate.

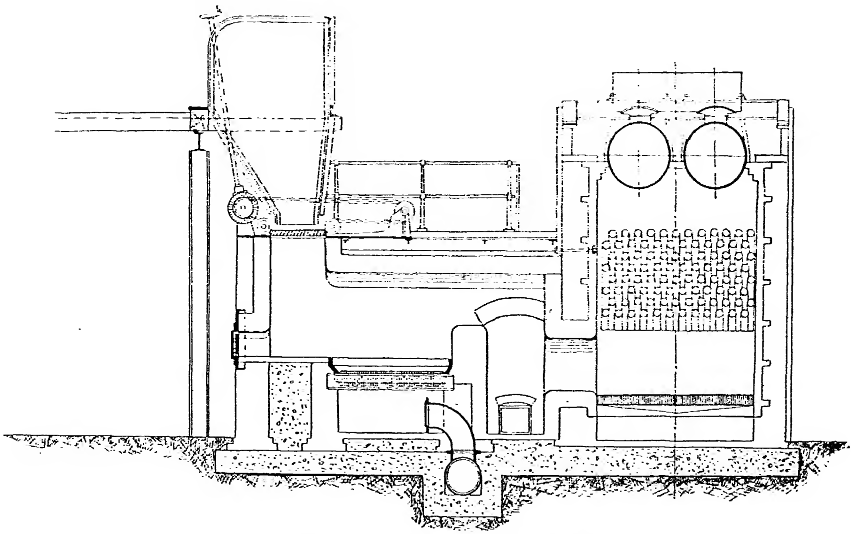

FIG. 14.—Marten's Patent Direct-charging Apparatus.

The "Horsfall" Patent Tub-fed Destructor.—Prominent among systems of automatic or mechanical charging is the Horsfall "tub-fed" type.

The refuse is delivered at ground-level, the vehicles discharging their contents through a hopper into a "tub," which is arranged in a pit. When the "tub" has been filled with refuse it is lifted by an electrically operated overhead travelling crane to the storage platform over the clinkering floor.

The tub, which will contain one cartload of refuse, is provided with hinged lids at its base, which are held closed by means of the rods and hooks by which the tub is suspended.

At regular intervals a cell is charged, a tub of refuse being lifted by the electric crane and placed on a cradle on top of the cell. The weight

of the tub causes the cradle to descend, and by a system of levers the charging door is lifted from a water-sealed seat and pushed to one side, permitting the base of the cradle to further descend into the mouth of the charging opening. As the crane is relieved of the weight, the hinged doors at the bottom of the tub open, when the refuse falls on to the grate beneath.

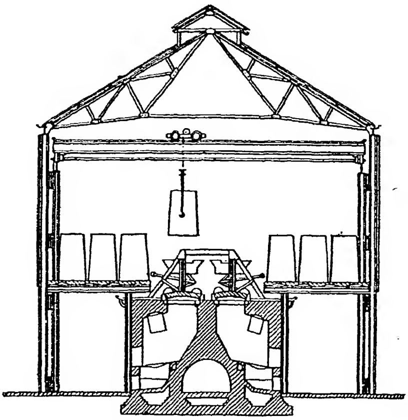

Fig. 15.—Horsfall's Patent Tub-fed Destructor. Cross-sectional view.

The grate is provided with small holes, and a very high-blast pressure is provided by fans or blowers. When the charge of refuse is completely burnt through, the clinker is withdrawn through a large clinkering door at the front of the cell; this door is provided with a small central door for inspecting and levelling the fire.

The gases leave the cell through an opening in the side near the top, and pass into a combustion chamber, thence to the boiler, dust catcher, and chimney.

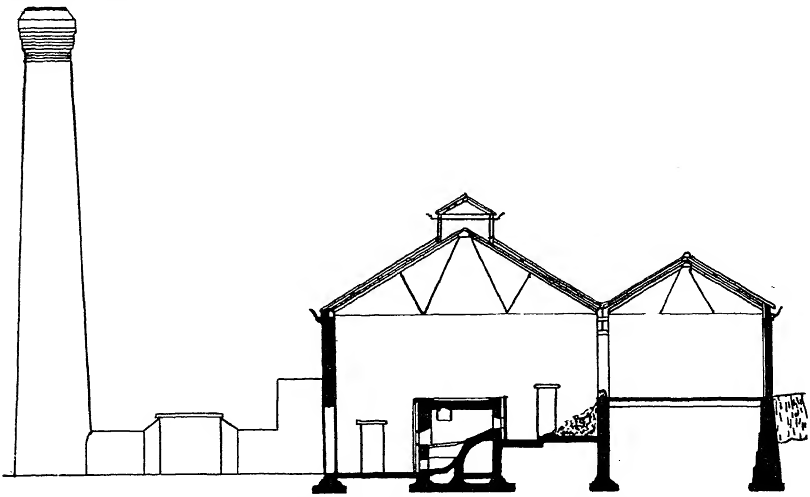

Fig. 16.—Horsfall's Back-fed Destructor at Dunoon. Longitudinal section.

The usual arrangement is to build the cells in units; a unit may comprise two or more cells, a combustion chamber, and a boiler. In some installations regenerative air heaters are included.

A typical "tub-fed" destructor is illustrated in fig. 15, which is a cross-sectional view of the installation at Greenock.

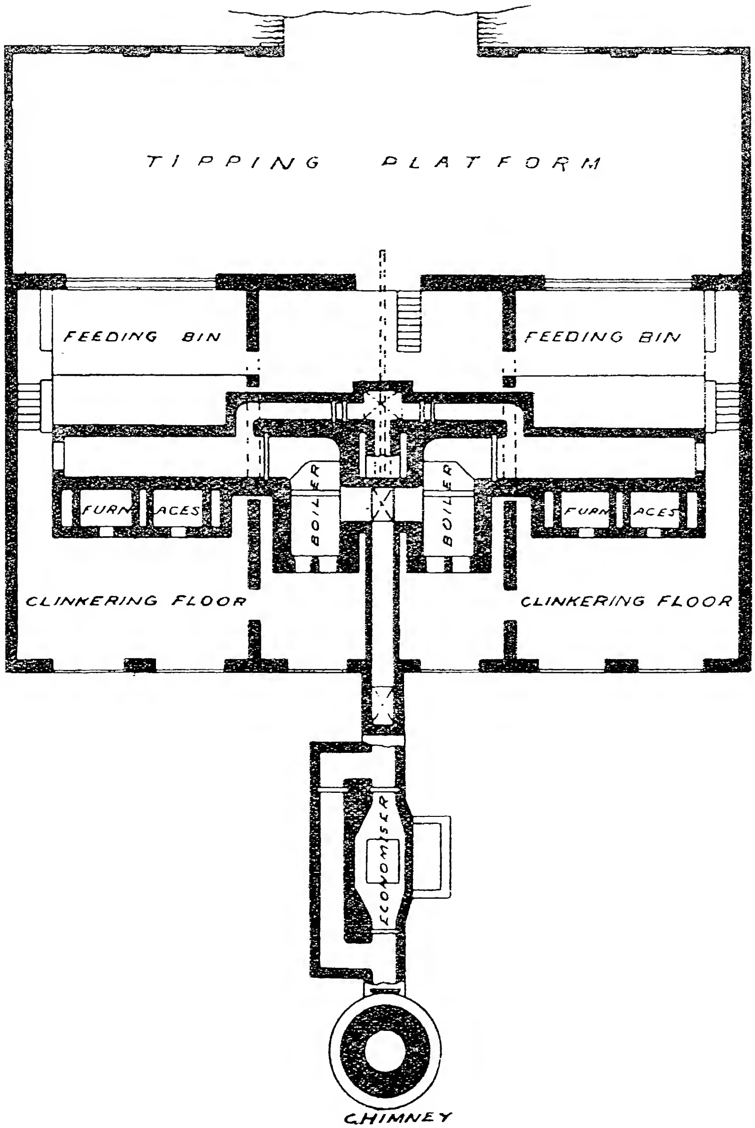

FIG. 17.—Horsfall's Back-fed Destructor at Dunoon. Plan.

Back Feeding.—The Horsfall back-fed destructor of the cellular type, as erected at Dunoon, N.B., is illustrated in figs. 16 and 17; it will

be observed that this scheme is well laid out, and the arrangement is exceedingly compact.

The Heenan "twin-cell" furnace, which was introduced about 1898,

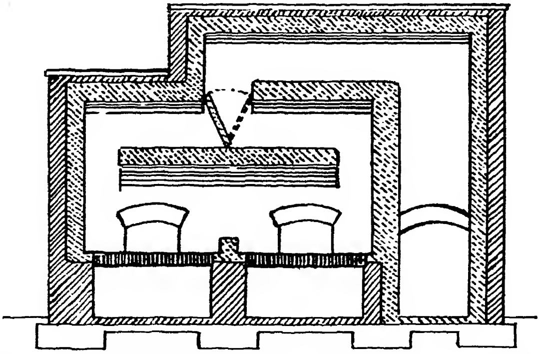

FIG. 18.—Heenan's original "Twin-Cell" Destructor. Section.

is illustrated in fig. 18. The design was novel, the idea being to charge each cell in turn, and so to direct the flow of gases alternately that low temperature gases should always pass over the incandescent fire before leaving the cell.

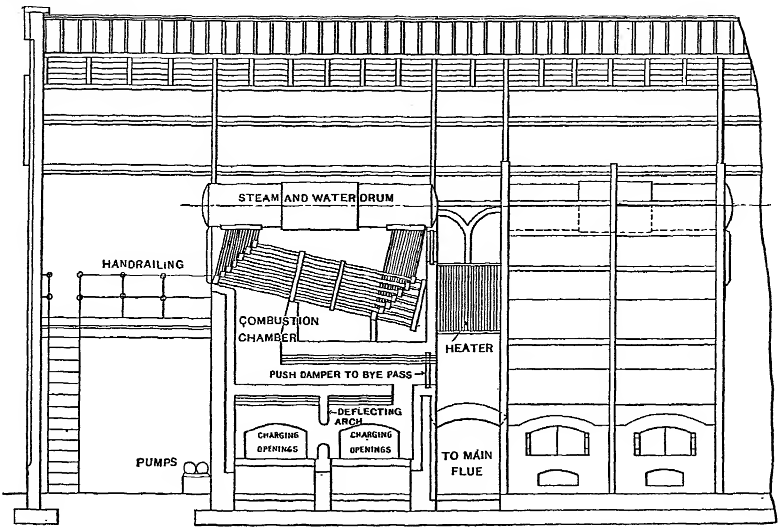

FIG. 19.—Heenan's improved "Twin-Cell" Destructor.

As originally designed, the "twin-cell" was provided with a damper to control the direction of the gases; this damper, which was continually exposed to high temperature, was abandoned in favour of the deflecting arch and single-outlet flue, as shown in fig. 19.

Heenan's back-fed destructor of the continuous-grate type is illustrated in fig. 20 which is a cross-sectional view; the form of hopper here shown is very useful indeed in all cases where considerable storage is not essential. The sloping back of the hopper reduces "trimming" to the minimum.

Other back-fed destructors of the continuous-grate type are the "Sterling" and the "Meldrum"; typical installations of the former are at Paignton and Yeovil, and of the latter at Dublin.

The Meldrum front-fed type of destructor is fully illustrated in the plan and sections shown in fig. 21, which is a very satisfactory and

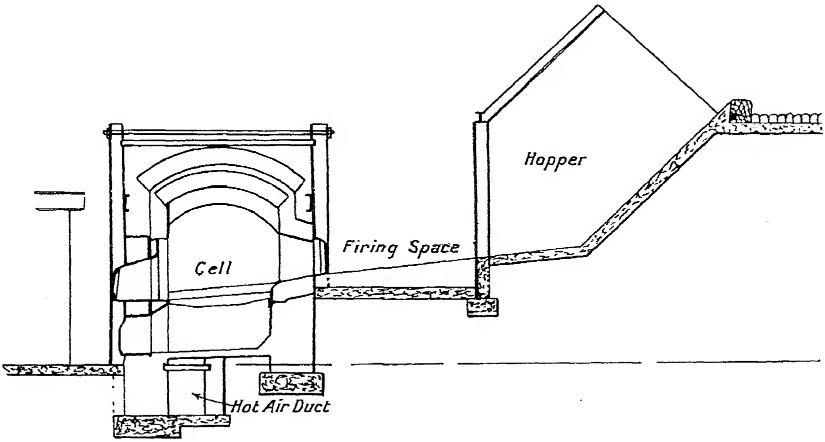

FIG. 20.—Heenan's Back-fed Destructor. Cross-sectional view.

economical arrangement for a single unit when it is proposed to duplicate the plant in the future.

It will be seen that two openings are provided between the furnaces and the combustion chamber. The author has found it desirable to close the opening nearest to the boiler; by so doing the gases are compelled to traverse the grates and the combustion chamber, with the result that the efficiency is increased, and the amount of dust passing into the boiler flues is materially reduced.

A plant arranged on such lines has been operated for thirteen weeks continuously, during which time about 3300 tons of refuse have been burned. After a run of thirteen weeks the whole plant is shut down for one week for inspection, overhaul, and cleaning.

One installation with which the author is acquainted has been thus operated for upwards of six years past, forty-eight weeks' work per annum being done by a single unit.

The hopper, as illustrated in fig. 21, is not satisfactory. The vertical back wall involves far too much "trimming." Where hoppers of this type have been adopted the author would advise the use of an adjustable

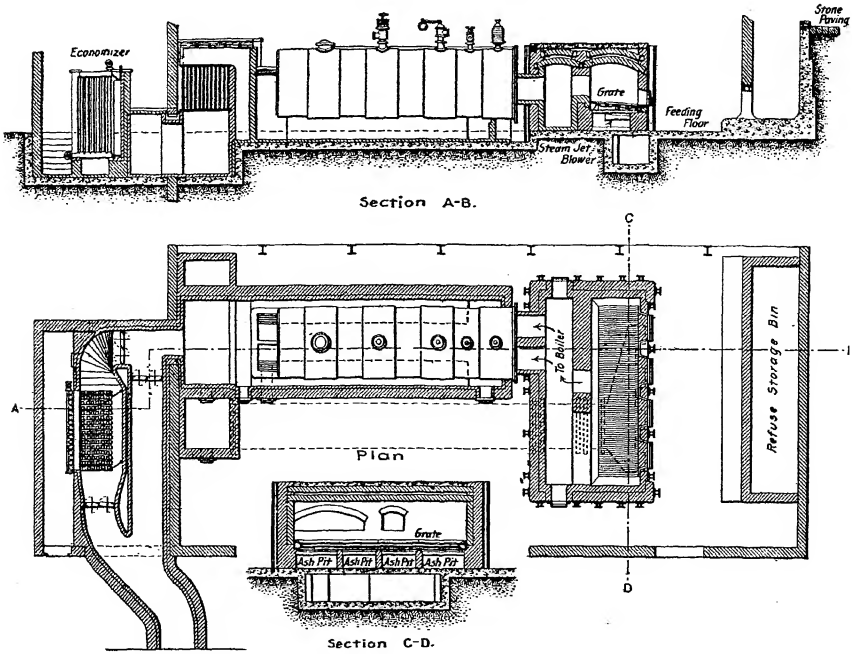

FIG. 21.—Meldrum's Front-fed Destructor at Watford. Plan and sections.

inclined wooden back, the angle of which may be altered as found desirable; it is then possible to project the refuse well forward, and thus avoid much labour in trimming.

Among other front-fed destructors of the continuous-grate type are the "Heenan" and the "Sterling," typical installations of which are described and illustrated in Chapter VI.

CHAPTER III.

SYSTEMS OF CHARGING DESTRUCTORS.

THOSE who have closely followed the methods employed for the charging or feeding of refuse into destructor cells cannot have failed to observe the preference shown for the back shovel-fed type of destructor during the past few years.

Introduced originally by the Horsfall Destructor Company some nineteen years ago, the back-fed destructor appeared to have a great future, but for some years it was left to the original makers to exploit this method of charging, and it was not adopted by the other makers of destructors until a few years since.

Under these circumstances, and in competition with top- and front-fed destructors, the number of back-fed destructors erected were comparatively few, while great headway was made with the front-fed destructor.

After a lapse of some years, the back-fed destructor came into prominence and was very actively exploited, mainly with a view to meeting the growing demand for shovel feed, and checking the adoption of the front-fed type. To such an extent has the back-fed destructor been advertised during the past few years that it is now in great demand, and at this time is offered by all the British makers, with but one or two exceptions.

While the author is of opinion that a back-fed destructor is a very useful type, he is also of opinion that, as at present designed, the back-fed destructor does not possess all those advantages which are claimed for it, and that some of the claims put forward are mere talking points.

When the back-fed destructor was first introduced a drying hearth was used, and instead of the refuse being spread over the grate from the back charging door, as is now done, it was merely heaped upon the drying hearth immediately inside the charging door.

In order to render this operation as easy as possible, the sill of the

charging door was arranged from 10 to 15 in. above the level of the charging floor, which was narrow, the fireman having to stand either on the refuse or in very close proximity thereto.

As the refuse had merely to be shovelled on to the drying hearth just inside the door, the height of the door sill was not inconvenient, although the conditions under which the fireman had to work were very unsatisfactory.

Now the curious point is that, although the hearth is but rarely used in connection with the modern back-fed destructor, the door sill has not been raised, and under such conditions the fireman has to cover the grate with refuse, which involves shovelling while stooping in a cramped position.

Another unsatisfactory feature is that the width of the charging floor is but little if any more than was the case with the earliest back-fed destructors.

It is true that the original back-fed destructor was of the "cellular" or isolated-cell type, while the modern back-fed destructor is of the "continuous-grate" type, but with this difference, and also the omission of the drying hearth, the modern back-fed destructor in general design is very similar to the earliest installations.

Among the claims made for the back-fed destructor are (1) that it presents satisfactory conditions from the labour standpoint, and (2) that it is cleanly and sanitary in operation.

Those who know anything about the work of a fireman will be aware that the operation of shovelling any fuel on to a grate which must be covered as evenly as possible can best be done if the door sill is at such a level as permits of the fireman assuming an easy and natural attitude when firing.

When the man is compelled to stoop and bend in order to look into the charging door and shovel the refuse evenly over 25 sq. ft. of grate, it is obviously very laborious; this work can be most efficiently done when the body is allowed to assume a natural position, and shovelling is an easier operation and is done in a more satisfactory manner if the man is able to assume an upright position.

While it is true that the fireman has to stoop to pick up the refuse with a front-fed destructor, the continuous stooping necessary with the back-fed destructor as at present designed is avoided, and the actual operation of shovelling the refuse over the grate is performed in an easy, natural position.

This is a point which appears to be constantly overlooked by those who investigate the comparative merits of back and front feeding.

Further, it is a point which would seem to have been ignored by destructor makers, although the lowering of the charging floor to the extent of about 12 in. would suffice to make the charging of a back-fed destructor as easy and satisfactory as the charging of a front-fed destructor.

It is impossible to ensure cleanly and sanitary conditions unless the arrangement of the refuse storage hopper in connection with the back-fed destructor is altered. Up to the present time, in almost every case the charging floor is much too narrow.

When the refuse is tipped into the hopper, much of it falls over the narrow charging floor, with the result that it is usually found that the fireman is standing in the refuse, and it is only when the contents of the hopper have been considerably reduced that the fireman has sufficient room to work in.

The reason for restricting the charging space and making the hopper narrow is to avoid "trimming," *i.e.* to deliver the refuse as close as possible to the destructor: while this does undoubtedly avoid the labour of "trimming," it is impossible to regard such an arrangement as cleanly or sanitary.

Again, one of the arguments advanced in favour of shovel feeding as compared with top feeding is that the former permits of cool storage of the refuse. It will be clear that, while this is very desirable, it is impossible if the refuse is stored so close to the destructor.

Another argument commonly used in favour of back feeding as compared with front feeding is that it is far more satisfactory to remove the clinker from separate doors immediately opposite to the charging doors instead of through the same doors.

At first sight there would seem to be much in favour of this course, but, upon consideration, it will be found that the objection to the use of the same doors for both operations is, to a very great extent, a sentimental objection, and based upon certain conditions which may or may not exist.

It is argued that unburned refuse may be removed with the clinker if the same doors are used for charging and clinkering; this may happen with a careless man clinkering, and, under precisely the same circumstances, it may happen with a back-fed destructor. Whether it will happen or not depends entirely upon the man, and it matters not which type the destructor may be; it is as easy to remove a small portion of unburned refuse with the clinker from the one type of destructor as the other.

When the drying hearth was used back feeding possessed an

advantage which it no longer possesses; the refuse was then spread over the grate from the front of the cell and clinkered from the same point. With the elimination of the drying hearth and the retention of the back feeding door at practically the same level for an altogether different operation, as already observed, the work cannot be done under either easy or satisfactory conditions.

When the level of the charging-door sill is raised, when an adequate charging space is provided, making it no longer necessary for the fireman to stand in the refuse, then the design of the back-fed destructor will be far more satisfactory; and as sentiment will always be a factor of importance, back feeding will continue to appeal to many.

Front Feeding.—The first front-fed destructor was erected at Hereford in 1897 by Messrs Meldrum; and although this system of feeding, as also back feeding, aroused much hostile criticism, remarkable progress was made. Stigmatised as primitive and insanitary, ridiculed in all quarters, and termed "spoon-feeding," the experience of a few years compelled those who had criticised to judge by the results obtained.

When once it was realised that the results were far in advance of anything recorded in connection with other systems of charging, then shovel feeding became popular, and the measure of its popularity can best be judged by the fact that practically every British maker now offers both back- and front-fed destructors.

The number of installations of back- and front-fed destructors is shown in Table X., while in Tables I., II., III., and IV. some of the results obtained are clearly set forth.

Front feeding, in common with back feeding, presents rational and exceedingly satisfactory combustion conditions if the destructor is operated as it should be. With all hand-fired furnaces with which coal is used as fuel, the highest working efficiency is secured by the introduction of *a small quantity of fuel frequently*, and the very best practice either in machine or hand firing with coal is based upon this system of working.

If this method of working is reproduced, so far as is practicable, in the shovel-fed destructor, then there is never any question as to the efficiency, provided always that the plant is well designed, and that the same regularity which is brought to bear in connection with the charging of the refuse is also found throughout the whole cycle of operation.

The author is of opinion that front feeding does possess certain distinct advantages over back feeding, the nature of which may be briefly

summarised as follows:—(1) The labour is *concentrated* at one point, viz. at the front of the destructor. (2) A rather smaller building will suffice, which has the effect of reducing the capital expenditure. (3) The cost of maintenance is less with a properly designed and well-built front-fed destructor than with any other type.

The concentration of labour is a manifest advantage in the operating cost, inasmuch as it is found that those who charge the refuse into the cells, either at the back or the top, to a large extent confine their attention to this particular work, whether it occupies all their time or not. In theory it would seem easy enough to arrange for those who charge to divide up their time and assist in clinkering, etc.; in practice it is found very difficult; and if charging does not absorb all the time, there is usually a definite loss in labour, and correspondingly a definite increase in the labour cost. With a front-fed destructor the labour is usually shared equally, and the whole of the staff charge and clinker the grates in turn.

It may be observed that, as a general rule, the storage hopper of a front-fed destructor is well arranged. Having in mind that the clinkering operation takes place between the front of the cells and the hopper, the hopper front is usually from 10 to 12 ft. from the front of the cells, the storage is cool, and the men charge the refuse under more cleanly and sanitary conditions than are usually found with back-fed destructors.

That the building for a front-fed destructor is narrower will be clearly understood; and if a reasonable charging and hopper space is provided with the back-fed destructor, this will inevitably still further increase the width and cost of the building for a destructor of this type.

Concerning the comparative cost of repairs and maintenance, the front-fed type has the advantage, because, all other things being equal, the destructor with the minimum number of openings has been shown to require the least repair, and the records of maintenance cost in connection with destructors of all types clearly shows that the front-fed type usually costs less to maintain than any other.

In well-built destructors of any type the main item for repairs is found to be in connection with the door openings at the front, back, and top. In the manipulation of heavy rakes, drags, and slices, the incandescent firebrick is worn away, broken, and dislodged; in some instances the walls are seriously weakened, and extensive repairs become necessary.

It is well to remember, when it is argued that the front-fed destructor is unsatisfactory because the clinker is removed from the

charging openings, that this is common practice with all hand-fired steam boilers. All boilers which are hand-fired are provided with front-firing doors only, and the clinker must of necessity be removed at this point. The common practice in burning coal is precisely the same as in burning refuse; a fire must be "burned down" before being clinkered; if this is done and the fireman is careful, very little combustible material is removed with the clinker, and this in spite of the fact that the grate is often very narrow, the fire door is small, and the conditions rather more difficult than with a destructor grate.

The tendency of the destructor fireman is not to clinker a fire before it is well burned, because the work is laborious and is put off as long as possible. Under these conditions there is a tendency to charge on top of a vitreous mass which is not in a condition to receive a fresh layer because the air supply is unable to effectively permeate the mass; hence, when the clinkering of a grate has been unduly delayed, at times the upper layer is not in a condition to be removed, and if removed with the clinker it is not an argument against the *type* of destructor, but, on the other hand, simply shows that the fireman is either careless or incompetent.

This may happen with a destructor of any type, and does occasionally happen even in the best managed works. The skilful or careful fireman, when removing clinker, always turns it over on the grate to shake off the loose and unconsumed portion, to furnish the bed for the next charge.

With the "continuous-grate" destructor of any type the clinkering of a grate demands care, because, even if there should be no loose or unconsumed material on top of the mass of clinker, there is always the possibility of removing with the clinker a small portion of unconsumed or partially consumed refuse from the adjoining grate or grates.

The point which the author is anxious to emphasise is that, while the possible removal of unconsumed refuse with clinker is said to be peculiar to the front-fed type only, this is incorrect, and those same conditions which conduce to this difficulty are common to destructors of every type having continuous grates.

As a general rule, the front-fed type is cheaper to install than any other type; and while there are reasons why the use of both shovel-fed types should be restricted to a destroying capacity of, say, 60 tons daily, yet, from every point of view, the front-fed destructor is perfectly efficient and satisfactory.

In the adaptation of a refuse destructor to existing boilers previously

fired with coal, the front-fed destructor can frequently be adopted with but the minimum of structural alterations, whereas very often the installation of a back-fed destructor is either impossible or prohibitive in cost, and this is equally true of the top-fed type.

Top Feeding.—It will be common knowledge that the first destructors were of the top-fed type; the first "Fryer" top-fed destructor was erected thirty-six years ago. Top feeding, which for many years was regarded as the only possible method of charging refuse, has not been generally regarded with favour during the past fifteen years, during which time most of the destructors erected have been of the front and back shovel-fed type.

As originally designed, the top-fed destructor was what may now be termed crude. While simplicity was a marked feature of the design, it was simplicity without efficiency.

The design of the early top-fed destructors is so familiar to every student that it is unnecessary to discuss the same at any length at this time.

The most unsatisfactory feature in the design of the Fryer destructor was the outlet from the cell into the main flue. The entire volume of gases left the cell at the back and near the top, passing over a bridge at the top of the drying hearth, thence downwards into the main flue, which was arranged partially under the drying hearth.

This method of exhaust was weak, inasmuch as the noxious gases and dust had direct and immediate access to the main flue; the slowly distilled gases from the refuse on the drying hearth were rapidly drawn into the main flue, where the temperature was always very low.

The first drastic improvement in the design of the top-fed destructor was the introduction of the front exhaust flue by Messrs Horsfall, the object of which was to ensure that the volume of low temperature gases liberated from the mass of refuse should pass over the active fire within the cell before passing therefrom; in short, as compared with the Fryer destructor, the passage of the gases was reversed.

The Horsfall top-fed destructor was the first satisfactory destructor of this type; the front exhaust with high temperature marked a great advance at a time when the top-fed destructor was in bad repute. The front-exhaust or outlet flue, while answering its primary purpose, however, was not entirely satisfactory, owing to the retention of dust at this point. With the deposit of dust the area was reduced; and if the dust was not frequently removed, the throttling of the gases at the cross flue had the effect of reducing the destroying capacity and causing back draught.

Fourteen years ago Mr George Watson thus defined top feeding:—

"With top feeding the refuse is merely pushed blindly in."[1]

While this fairly describes the operation in connection with the earliest top-fed destructor, it is equally applicable to the modern plain top-fed destructors.

As a general rule with all destructors of this type, the capacity of the charge is fixed by the man or men on top; there is no regularity, the charge may be half a ton, or it may be one and a half tons; usually the charges are far too heavy. A heavy charge means a periodical idle spell for the man, and heavy charges therefore are favoured.

There are already distinct signs that the top-fed destructor of the future will embody apparatus by which each charge will be definitely measured, while the charges will be comparatively small—about one cubic yard—and the operation of charging will be controlled by the man in charge of the destructor at the clinkering floor level.

Development along such lines as these is but the natural outcome of a system so tersely described by Mr George Watson, an haphazard system of feeding, which must inevitably be unsatisfactory.

Uncontrolled and widely varying charges involve inefficiency, not only with top-fed destructors, but with the back- and front-fed types, and also with all coal-fired furnaces, and it is frequently found that carelessness in charging is the direct cause of nuisance and complaints concerning the nature of the discharge from chimneys.

With the early top-fed destructors the refuse was stored on the top of the cells, and was generally raked or dragged into the charging openings.

In many cases the storage platform was in effect an external drying hearth, the heat from the cells underneath causing the refuse to stew until the atmosphere of the building was foul in the extreme. Much of the dry refuse was quickly converted into dust. In this fœtid, dust-charged atmosphere, at times knee-deep in the refuse, the work of charging was done. Under such circumstances, when the building was not completely closed, the escape of foul gases and dust was unchecked, and at times the nuisance from the building was more serious than from the chimney.

As the refuse was dragged or raked into the charging openings, the loose and freshly delivered material from the top of the mass was usually handled freely, with the result that the stale and foul layer next to the hot surface of the platform was allowed to remain, moisture drained by compression on to the hot surface and was slowly evaporated.

[1] "Watson on Refuse Furnaces," *Proceedings of the Institution of Civil Engineers*, vol. cxxxv., session 1898-99. part i.

In order to avoid the many unsatisfactory features of storing the refuse directly on top of the cells, in some installations a chequer-plate storage platform, arranged on joists a few inches above the top of the cells, was provided; while this departure to some extent improved the working conditions, it failed to satisfy the growing demand for cool storage of the refuse and more sanitary conditions.

With a view to overcoming the objectionable features of top feeding already discussed, a large steel storage hopper was provided above and at the rear of the destructor cells, the base of the hopper being inclined; this hopper provided cool storage, and was so arranged as to facilitate charging, while also ensuring the charging of the refuse from the bottom of the hopper.

So slowly were these improvements in connection with the top-fed destructor evolved that by the time this type of destructor embodied those features which ensured sanitary working conditions, the front- and back-fed types were firmly established, with such satisfactory results that top feeding, except for large installations, is but rarely adopted now.

One feature of some importance in connection with destructor storage hoppers which has received but little attention is the closing of the top of the hoppers, which is desirable whether the destructor be fed at the top, back, or front.

With tipping platforms, whether exposed or entirely covered in, a closed hopper is preferable: at times hoppers are very full, and where the tipping platform is exposed, paper and very light refuse is blown and scattered in every direction. Where the tipping platform is enclosed, the atmosphere of the building will be improved if the hoppers are covered, and the refuse is then only exposed while being discharged therein.

Having in mind the small additional cost of an enclosed hopper, it is strange that it is so rarely asked for, while it is even more strange that the British destructor makers, to a large extent, ignore this useful feature.

Generally speaking, the cost of a top-fed destructor is considerably in excess of the back- and front-fed types. The building must be more lofty, and will accordingly be more expensive. If an ordinary inclined approach roadway is provided, this will be more expensive than for a back- or front-fed destructor, as the level of the tipping platform must be so much higher.

If, instead of an inclined approach roadway, the refuse is hoisted and transported by an electric crane, the building must be still further increased in height, and it has been shown by experience in several instances that it is of vital importance to provide cranes in duplicate.

Owing to lack of space for an inclined approach roadway it has been necessary, in connection with a number of destructor installations, both at home and abroad, to provide an electric crane. In some few cases hoists have been installed, but their record generally is unsatisfactory. Both hoists and cranes have usually been installed singly: the necessity for duplication has not become apparent until a breakdown has occurred. Some time ago the author visited a destructor works on the Continent, where, owing to the breakdown of the crane, the works had been closed for two weeks, during which time hundreds of tons of refuse had accumulated.

If the necessary space for an inclined approach road is available, it is advisable to adopt this course rather than either of the alternatives. Taking into account every factor, it is not only the most satisfactory course, but frequently the cheaper one.

In repairs and maintenance cost the top-fed plant is invariably more costly than the shovel-fed types. The top-charging openings weaken the crown of the furnace, and the cost of repair and maintenance at this point alone is frequently in excess of the total repairs cost in connection with a front- or back-fed destructor.

For many years past the idea has been prevalent that the labour cost per ton of refuse destroyed with a top-fed destructor is lower than is the case with the shovel-fed types. As a matter of fact, such statistics as have been available from time to time conclusively show that shovel feeding is cheaper than top feeding.

In making a comparison of this kind it is but fair to disregard some of the phenomenally low test results published in connection with both types, basing the comparison upon average working costs under normal conditions of operation.

In the larger installations a small advantage in the labour cost is frequently shown, but if the working conditions are closely examined it will invariably be found that the charges are too heavy, and that the working efficiency is not comparable with shovel-fed plants.

For the disposal of excreta with refuse a top-fed destructor is often desirable, and there is undoubtedly a future for this type both at home and abroad; but the author is of opinion that the future, to a very great extent, depends upon the combination of apparatus for securing fixed, definite, and comparatively small charges, a system of operation which is of vital importance.

Mechanical Charging.—In a careful survey of destructor practice during the past thirty-five years it will be observed that simplicity has been shown to be of paramount importance. In the evolution of the

destructor the highest working efficiency has been reached with a furnace of simple form, *i.e.* the "continuous-grate" furnace; and whether top fed, back fed, or front fed, this simple form of furnace has shown a marked superiority in working efficiency over the "cellular" or isolated cell furnaces.

Coincidently with the introduction of the "continuous-grate" destructor, the forward movement in final and sanitary refuse disposal began; and it may be claimed that simplicity in design with reliability in operation account for the rapid adoption of British destructors, not only in this country, but in almost every civilised country in the world.

At this time, when there is a disposition in England, Germany, and the United States to introduce complicated mechanical apparatus for charging refuse, it is worth while to bear in mind the opinions of those competent to judge, and to endeavour to discover the reasons why there is a disposition to disregard an experience of many years, an experience which has conclusively proved that simplicity in design is essential.

In a paper read before the Institution of Engineers and Shipbuilders in Glasgow on March 20, 1906, Mr H. Norman Leask said:—

"Five years ago[1] it was common to see expressed in specifications a desire to receive schemes for charging furnaces mechanically, and much money, time, and trouble has been spent in endeavouring to arrive at this desideratum. Up to date it has not been achieved with any marked degree of success, and it may be said with a great deal of truth that plants giving the greatest satisfaction are those in which *no such mechanical means exist.*

"The material could, of course, be treated primarily, disintegrated, and reduced to a uniform size, and then fed into the furnace in a simple manner; the cost of such machinery, and the maintenance and labour attending the same, however, *exceed that of charging the furnace by hand.* The author has had the opportunity of inspecting such apparatus at work, and of verifying these facts.

"It is not a difficult matter to devise a furnace into which large quantities of refuse can be tipped; it is, however, a grave question whether it is advisable to proceed in this manner or not. If whole cart-loads of refuse are tipped into a furnace no opportunity of selecting and varying the material is permitted, *nor can it be claimed that the charging of a furnace with a ton of refuse at a time is a scientific way of obtaining good combustion.* It must necessarily mean great fluctua-

[1] "Refuse Destructors," by Mr H. Norman Leask, *Transactions of the Institution of Engineers and Shipbuilders in Scotland,* 49th session, 1905–6, vol. xlix., part vi.

tion in temperature, and it is questionable whether any saving of labour results.

"Picture a load of market refuse being discharged into a furnace and subsequently a load of paper and straw, then a load of ashes, then large quantities of shellfish and tins: can anyone say that such a proceeding gives good results for a very large plant connected to a common chamber? Where it is merely a question of getting rid of the refuse there might be an excuse for such an arrangement, but under no other circumstances could such a proceeding be justified.

"From personal experience on this point, the author has found that in some districts and at certain seasons of the year such an arrangement could be worked with fair results, but it is certainly not applicable to all kinds of refuse; and from trials made with a view to ascertaining the effect on evaporation by charging at different intervals he has found that *by trebling the number of charges in a given time—the same quantity being burnt in that time—that the evaporative efficiency rose* 20 *per cent.*"

Mr Frank Watson, in a paper read at the Exeter Congress of the Royal Institute of Public Health in 1902, said:—

"The inventor, however, is proverbially sanguine, and in attempting to introduce a new and untried scheme will usually agree to any conditions which may be imposed in order to get the scheme adopted, his faith in his own inventions being in inverse ratio to his experience of their results.

"Complicated mechanism designed to save labour is frequently brought forward in connection with these plants. It should always be remembered that the conditions under which a destructor works are all against the success of mechanical arrangements situated within the furnace. Every appliance, whether for opening or closing doors, producing the necessary forced draught, or charging or clinkering the furnace, should be of the simplest and most direct character.

"An apparent economy is often entirely discounted by the cost of maintenance, and, what is still more serious, by the stoppage of the works during repairs." [1]

In these two clearly expressed opinions is the same plea for simplicity. Mr Leask mentions at least two points which are well worth careful consideration; he refers to the charging of a furnace with a ton of refuse at a time, and observes that it cannot be claimed that this is a scientific way of obtaining good combustion.

[1] *Recent Practice in Refuse Disposal and Utilisation Plants*, by Mr Frank Watson, The Royal Institute of Public Health, Exeter Congress, August 1902.

Now, as a matter of fact, there are on the market at the present time mechanical charging devices which put into a cell, not one ton at a time, but in some instances nearly two tons; on the Continent there are other charging devices which have a capacity of about 15 cwt.; but in almost every instance the latter have a grate area so small that, from the point of view of combustion conditions, the smaller charge is as unsatisfactory as the larger charge.

In considering the conditions obtaining when these charges are introduced into the cell, it is necessary to remember that the clinker from a previous charge has just been removed, which operation may have occupied about twenty minutes, having in mind its percentage as compared with the weight of refuse charged.

During this time the door has been open, the cell has been idle, the firebrick lining has cooled, the temperature has fallen to the extent of from 800° to 1000° Fahr. and sometimes more. With a cell in this condition the charge is introduced on to the grate, it may be a 2-ton charge on 25 sq. ft. of grate, it may be a 15-cwt. charge on 9 sq. ft. of grate, the mass may be 4 ft. or more in thickness, and lying close, as the result of the fall and impact.

The forced draught is put into operation, and as the air supply is forced through the mass dense volumes of heavy and noxious gases are driven off and pass into the main flue. Gradually ignition takes place and the cell temperature rises; probably in about half an hour the normal working temperature has been reached. As the mass burns and settles down for a time the air finds its way more readily through the fire, with the result that the dust is carried over into the main flue and boiler setting in considerable quantities.

Further, unless the forced draught is carefully regulated to suit the changing condition of the fire, the excess of air passing through the fire and into the boiler and main flue will be serious from the point of view of efficient combustion.

In order to realise clearly the extraordinary conditions presented for the combustion of 2 tons of refuse introduced in a single charge into a cool cell, it is worth while to compare the same with a shovel-fed destructor burning say 15 cwt. per grate (25 sq. ft.) per hour, and clinkered every two hours.

With this plant the clinker is removed in about ten minutes, during which time the temperature falls, say, 500° (the temperature being well maintained, owing to the active operation of the adjoining grate). Refuse is shovelled in on top of the live fire, shaken off the clinker, the forced draught is put into operation, and in ten minutes the normal

working temperature is easily reached; the shovelling in of the refuse then proceeds at intervals with a well-maintained furnace temperature.

Owing to the greatly reduced air pressure which is employed there is no trouble with dust; the excess air is reduced to the minimum, and generally rational combustion conditions are conduced to.

From the combustion point of view there is a vast difference between a mass of refuse from 3 to 4 ft. or more in thickness and a fire which is never more than 18 in. thick, and which only reaches this condition *gradually* as the result of periodical small charges.

Imagine for a moment the result of introducing instantly one ton of coal into a furnace, and compare the same with the rational periodical introduction of small quantities at a time; under the latter conditions the furnace temperature is well maintained, under the former conditions the fire would be smothered and useless.

While there is a very wide difference between a rich and homogeneous fuel and refuse, yet there are certain clearly ascertained and fundamental conditions, in so far as efficient combustion is concerned, which apply equally well to both.

A further point mentioned by Mr Leask is of more than passing interest. Referring to the tipping of a cartload of refuse into a cell he says:—

"No opportunity of selecting and varying the proportion of material is permitted."

A cartload or a large refuse receptacle may contain such articles as tins in considerable number, a pail, some hundredweights of offal, or much other material which it is foolish to introduce into the destructor at all, or very wet and offensive material which could be disposed of at suitable times, preferably in several charges or in two or three cells.

The system, however, does not permit of any grading or selection of the refuse; that which is in the cart or refuse-charging receptacle must go bodily into the cell, its composition is unknown, the demand for steam may be heavy, and this is unfortunate, but it is the system.

It must be obvious that this is a serious weakness, inasmuch as the selection of a charge of material suitable for any one cell under certain trying conditions is practically impossible. There are times when it is very desirable that the refuse should be graded; there are obvious advantages in being able to prevent quantities of tins and an occasional pail from being charged into a cell only to clog the fire, and eventually be removed practically in the same condition as when charged.

Mr J. A. Robertson, M.I.E.E., Burgh Electrical Engineer of Greenock,

in a paper[1] read before the Glasgow Section of the Institute of Electrical Engineers, made the following observations:—

"The principal advantage of the system is, of course, its comparative cleanliness. . . . The disadvantage of the system is that it prevents any selection or proportioning of the charges, while the deposition of a whole cartload of green refuse into a furnace at one charge is apt to cause fluctuations of temperature, with consequent variation in steam pressure."

The advantages of grading and selecting the component portions of a charge have been clearly demonstrated in connection with shovel-fed plants, and is considered to be so important that the German engineers take care to grade the refuse on the tipping platform before filling the charging shutes and mechanical charging devices. In the United States it is found very desirable to give considerable attention to the grading of refuse, and with low grade refuse, or when it is required to burn garbage in any quantity, preliminary grading is of vital importance.

When the author was inspecting an important destructor works in Northern Europe where charges of about one and a half tons are introduced three times in one day, he saw a fire smothered with a heavy charge which failed to ignite, and had to be raked out on to the clinkering floor, shovelled into its receptacle, and hoisted on to the charging platform.

This confirms the opinion of Mr Leask that "it is certainly not applicable to all kinds of refuse." At the works in question, bad as the refuse was, it could have been burned had it been possible to grade the same, but even then it would have been burned at a comparatively low temperature.

Refuse of low calorific value will never be efficiently destroyed with a freedom from nuisance unless it is to some extent graded and charged in comparatively small quantities, and the sooner this is recognised the better for the destructor engineer and the municipal authority.

After inspecting some eight installations, comprising mechanical, top- and back-fed destructors in Scotland and England, during December 1909, the cleansing sub-committee of the Aberdeen Corporation reported as follows:—

"The sub-committee are of opinion that the type of destructor most suited for the Aberdeen refuse is *the continuous-grate destructor with back hand feed.* The examples of the continuous-grate destructor inspected by the sub-committee appeared to give a very thorough combustion of the refuse itself and of the distilled gases.

[1] "Electricity Works and Refuse Destructors," by Mr J. A. Robertson, M.I.E.E.; see *Proceedings of the Institution of Electrical Engineers* (Glasgow Section), 1909.

"The sub-committee believe that back hand feeding, which closely resembles ordinary furnace stoking, is the most effective in securing a proper distribution of the raw refuse over the grate, and should give good results for steam-raising purposes, as well as in the complete destruction of the refuse.

"Mechanical feeding adds considerably to the cost of the plant, and makes the destructor more complicated and liable to repair without appearing to reduce sensibly the cost for labour.

"Its advantages are most apparent where the refuse is of such a stale character that it ought to be transferred to the destructors with the least possible handling."

A point of considerable importance in connection with mechanically-fed destructors is the fact that, as a general rule, no provision is made for an alternative method of charging in the event of breakdown. Even if such a course is possible, it involves great inconvenience, and a material increase in the labour cost.

CHAPTER IV.

DESTRUCTORS COMBINED WITH SEWAGE WORKS.

SINCE 1897, when the first destructor combined with a sewage pumping station was erected at Hereford, considerable progress has been made, and at the present time combined undertakings of this kind are either in operation or in hand for no less than seventy-four cities and towns.

As a general rule, the refuse of a community, if efficiently burned, will provide more than sufficient steam to pump the whole of the sewage. There are cases where the quantity of refuse available is much in excess of that required for supplying the necessary steam for pumping, while in other cases, owing to an abnormal lift or other peculiar local circumstances, the refuse is insufficient; such cases, however, are rare.

In some few towns, the amount of refuse is not only ample for providing the steam required during the week, but sufficient material is stored to furnish the steam required on Sundays. In such cases, with but few exceptions, no coal-fired boilers are provided, and no fuel other than refuse is ever burned, unless the collection of refuse is delayed.

The combined destructor and sewage works at Epsom, Surrey, with the design of which the author was closely concerned some nine years since, is a typical example of this kind, and has been remarkably successful. There could be no more convincing example of the possibilities of a combined destructor and sewage works than this, having in mind that steam is not only provided for pumping the whole of the sewage of the town for three hundred and sixty-five days every year, but, in addition to the normal volume of Epsom sewage, the sewage of the several large institutions of the London County Council is also dealt with.

What this additional volume amounts to will be clear from the following figures, which have been kindly furnished by Mr E. R. Capon, the engineer and surveyor to the Epsom Urban District Council:—

Average volume of Epsom sewage pumped daily	600,000	gallons.
" " lifted by Shone ejectors daily .	30,000	"
" " of sewage from London County Council Asylums, daily dry-weather flow	300,000	"

Ejectors are also used for lifting sludge and distributing the same on the land.

In cases where the amount of refuse is insufficient for a seven days' steam supply weekly, it is desirable to install water-tube boilers arranged for supplementary or separate coal firing with the destructor to avoid the waste of fuel in getting up steam in a cold boiler on Saturday evenings.

The water-tube boiler is suggested for this purpose, because (1) it may be easily arranged for alternatively firing with destructor gases and coal, whereas the Lancashire or Cornish boiler is unsuitable for the double purpose; and (2) because after six days' use much heat is stored in the firebrick lining of the water-tube boiler setting, and the change over from destructor firing to coal firing is possible without any loss, and with but the minimum of inconvenience.

Where it is necessary to change over from destructor firing to coal firing for the Sunday and get up steam from cold in a separate boiler, there must be a definite loss. In a recent case with which the author is familiar, it was found that upwards of one ton of steam coal was used every Saturday night to get up steam, and some three tons of steam coal during the Sunday; hence each Sunday stoppage of the destructor involved the use of four tons of steam coal, over 25 per cent. of which was, to all intents and purposes, wasted. To avoid this loss, and to save the labour in the coal-fired boiler-house on Sundays, it was suggested that the steam main in the sewage works should be connected up to the steam main in the adjoining electricity works; this has been done, with very satisfactory results. The electricity department are merely paid for steam supplied at so much per hour, the sewage works save that which for some years was wasted, and no coal is now purchased.

As a general rule, the sewage works are so located as to make the combination of the destructor satisfactory from the point of view of cartage cost. While sewage works are not centrally located as a rule, and while their position in some towns is such that the cartage cost for disposal cannot be reduced, if the refuse is taken to this site it will be found in the average case that the cartage cost is not increased thereby, having in mind that in some cases the refuse tip adjoins the

sewage works, while in many cases the tip is considerably further than the sewage works.

There are exceptional cases where the sewage works are located at such a distance as to make the cost of cartage prohibitive, but such cases are few in number.

While the provision of a destructor at an electricity works is frequently objected to from a sentimental point of view, it is rarely, if ever, that its installation at a sewage works is questioned by the sentimental or aggrieved ratepayer, who, as a rule, prefers to leave the sewage works severely alone.

So satisfactory has this combination proved in all parts of Great Britain that it is one which should receive the careful consideration of all local authorities who have yet to face the problem of final and sanitary refuse disposal.

Many local authorities have installed suction gas plant at sewage works, while others have put in gas engines for town gas or oil engines. When deciding upon the form of motive power to be installed, the possibilities of the future would frequently appear to receive but little, if any, consideration; hence it is that when the time arrives to seriously consider the refuse disposal problem, in many of the smaller towns it is not possible to utilise the steam from the refuse without superseding gas or other plant, or using the same for stand-by purposes.

When contemplating the installation of pumping plant at a sewage works, it, to say the least of it, is a short-sighted policy to disregard or fail to take into consideration the disposal of the refuse. The author is aware that in actual labour cost, and in many instances in capital cost, the alternative form of motive power is cheaper, but the fact remains that sooner or later the refuse must be disposed of finally, and if the steam can be fully utilised at a sewage works, the destructor must be a more profitable investment than if erected as a destructor pure and simple.

When it is borne in mind that sooner or later most local authorities are faced with the refuse disposal problem in a more or less acute form, and bearing in mind that the sewage pumping station is usually a convenient site for a refuse destructor, the author is of opinion that gas or oil should only be adopted as the motive power at a sewage works under very exceptional conditions.

In not a few cases, when the question of refuse disposal has to be faced, the municipal engineer finds it impossible to suggest a means for utilising the steam, and his estimated operation cost is accordingly higher than would be the case if the steam could be used. Under such

circumstances it is frequently found that he had suggested the provision of a destructor at the sewage works some years before, but was overruled by those who were unable to take a comprehensive view; their concern was to snatch the economic advantage of the moment and let the future care for itself. Had this policy not been pursued, the number of combined destructor and sewage works now operating would be greater.

The saving of a coal bill at a combined works is not the only point of interest, nor does it represent the only saving effected. For the bacterial treatment of sewage immense quantities of destructor clinker have and are being utilised, and in many cases where this was previously purchased a considerable saving has been effected as the result of utilising the clinker for this purpose.

At some works, coke and coke breeze which had been used for filtration purposes, and which had disintegrated and become foul, has been passed through the destructor with the refuse and incorporated with the clinker, and has been again used for the filter beds.

The Tables I. and II. were prepared by the author in June 1905 at the request[1] of the Royal Commission on Sewage Disposal, and represent what was being done at that time in combined works. Table III. is a supplementary table, and records, with the exception of those installations marked thus $\surd$, some data in connection with the combined undertakings erected since June 1905, and up to the present time.

A long and extensive experience of steam plant at sewage pumping stations where coal is used has convinced the author that, for the most part, these works are operated on exceedingly uneconomical lines. With but a few exceptions the fuel bill is out of all proportion to the work done; the question of fuel economy would appear to be generally neglected.

To a large extent this accounts for the extraordinary economy effected at many sewage works where destructors have been installed, and for precisely similar reasons suction gas plant has shown a considerable economy in a number of works. When considering the economy to be derived by the use of suction gas plant it should be remembered that it is rarely compared with a modern high-class steam plant economically operated, but it is usually compared either with an obsolete and uneconomical steam plant, or plant which might easily be operated on far more economical lines if the questions of fuel economy and steam saving received that attention which they merit.

In the adaptation of destructors to existing coal-fired boilers at

[1] See *Fifth Report of Royal Commission on Sewage Disposal*, Appendix X., No. 1, 1908.

TABLE III.—DESTRUCTORS COMBINED WITH SEWAGE WORKS.

		Maker.	Type.	No. of Cells.	Boilers.	Remarks.
1	Aldershot	Heenan	Back-fed	2	1 Cornish	Clinker used for filter beds. See Tables I. and II.
2	Buxton	Do.	Do.	3	2 water-tube	Do. do. Value £130 per annum.
3	Basingstoke	Manlove	Front-fed	2	1 Babcock	New installation.
4	Bedford	Do.	Mech.-fed	4	2 Do.	Do.
5	Chester	Heenan	Do.	...	Do.	Do.
6	Chiswick	Horsfall	Back-fed	4	1 Do.	Supplementary plant gas engines.
7	Chadderton	Manlove	Top-fed	2	...	New installation, gas engines to be used as stand-by plant.
8	√Chesterfield	Horsfall	Back-fed	4	2 Babcock	
9	√Cardiff	Meldrum	Front-fed	8	4 Do.	
10	Droylsden	Heenan	Back-fed	2	1 Cornish	
11	√Ealing	Fryer & Warner own	Top-fed	10	3 multitubular	
12	Featherstone	Manlove	Do.	2	1 Babcock	Clinker used for filter beds. Annual value £127.
13	Felixstowe	Meldrum	Front-fed	2	1 Cornish	
14	Frome	Dawson & Manfield	Do.	2	1 Lancashire	New installation.
15	Guildford	Manlove	Top-fed	4	2 Babcock	
16	Gosport	Do.	Back-fed	2	1 Do.	
17	√Glasgow	Meldrum	Front-fed	8	2 Lancashire	
18	Hampton	Horsfall	Do.	2	1 Cornish	Saving = one-third of coal bill.
19	Hoddesdon	Hughes & Stirling	Do.	2	1 Babcock	A Cochran boiler is installed for use when the destructor [is out of service.
20	Ilkley	Horsfall	Back-fed	2	1 multitubular	
21	Manchester, Gorton	Do.	Do.	4	1 Babcock	
22	√Nuneaton	Meldrum	Front-fed	3	2 Cornish	
23	Portsmouth	Heenan	Mech.-fed	8	2 Babcock	Lancashire boilers are used for coal firing when necessary.
24	Sudbury	Meldrum	Front-fed	4	2 Cornish	No coal-fired boilers.
25	Stratford & Wolverton	Do.	Do.	2	1 Babcock	Do. do
26	*Southampton (1)	Warner	Top-fed	4		Approximate saving in coal bill, £2000 per annum.
	Do. (2)	Manlove	Do.	4	3 Do.	One coal-fired boiler is also used during stormy weather
	Do. (3)	Own design	Do.	4	1 Lancashire	and holidays.
27	Surbiton	Heenan	Back-fed	...	Babcock	New installation.
28	Stroud	Manlove	Do.	2	1 Lancashire	Do.
29	Sowerby Bridge	Dawson & Manfield	Do.	2	1 Babcock	Gas engine as stand-by.
30	Saltley	Heenan	Top-fed	8	2 Lancashire	
31	Seaford	Meldrum	Back-fed	2	1 Babcock	New installation.
32	Skegness	Manlove	Do.	2	Do.	Oil engines are used for stand-by purposes.
33	Twickenham	Meldrum	Front-fed	4	2 Lancashire	A Babcock boiler is installed for coal firing when necessary.
34	Worthing	Heenan	Back-fed	2	1 Babcock	Gas engines are used when the destructor is out of service.
35	Yeovil	Hughes & Stirling	Do.	2	Do.	New installation.

Except those installations marked √, all the above have been erected since 1905. * This appears in Tables I. and II., but is here brought up to date.

sewage pumping stations much might be done. There are a considerable number of such works where expensive fuel is being used. In many instances the boilers are suitable and need not be reset, the existing chimney also would suffice, while the structural alterations required are neither serious nor costly; in short, the destructor could be provided at the minimum of cost. Among sewage works where destructors have thus been adapted are—Eccles, Hereford, Aldershot, and Nuneaton; that much more has not been done along these lines is a matter for regret, having in mind the wasteful conditions prevailing at many sewage works.

It is but fair to observe that in some cases the existing boilers are too small, or for other reasons are unsuitable, and the chimney is not always of sufficient area or height, but such cases are few.

The record of combined works is so satisfactory, the possibilities of the combination are so unique and comprehensive, that one wonders why a greater number of such combined undertakings have not been established.

Being engaged in municipal work, it gives the author no pleasure to state that the reason why this combination has not been more widely adopted is mainly due to either indifference or ignorance upon the part of councillors. Many schemes carefully prepared by municipal engineers fail to materialise because they are adjudicated upon by those who neither know nor take the trouble to endeavour to understand what is involved.

When the municipal engineer is given that credit which is due to him, when the councillor ceases to interfere in that which he cannot comprehend, and no longer obstructs because he is indifferent, then this combination which has been so strikingly successful will be far more extensively adopted.

CHAPTER V.

DESTRUCTORS COMBINED WITH ELECTRICITY WORKS.

Seventeen years have passed since steam from a destructor plant was first combined with an electricity works, and nearly twelve years have gone by since steam at a pressure of 200 lbs. to the sq. in. was first generated at Darwen, and utilised in the adjoining electricity station.

It was confidently predicted that the combination would prove to be a disastrous failure, and that the experience of a very few years would serve to silence every advocate of the combination. On the contrary, there are at this time upwards of seventy-six combined destructor and electricity works either in operation or in course of erection in the United Kingdom, and some seventeen combined undertakings in other countries.

During the past few years the attitude of electrical engineers has changed considerably, and there has been a disposition to carefully consider the combination on its merits. Instead of hostility there has been a readiness to co-operate, and this has had the effect of eliminating many of the unsatisfactory features of the earlier installations.

The design and arrangement of the buildings and their ventilation have been improved to such an extent that the dust trouble in the engine-room—a source of frequent complaint some years since is now no longer heard of. Considerable attention has been devoted to the steam generating plant and its accessories, with the result that the working efficiency has been materially improved.

The financial arrangements, as between the electricity committee and the sanitary or health committee, concerning the basis of payment for the steam supplied, which at one time threatened to be a subject of never-ending argument, is now but rarely heard of. Doubtless in many cases it has been settled by the electrical engineer, whose offer, as a general rule, is now far more liberal than was the case a few years since,

when there certainly was a disposition to set far too low a value upon the steam.

Much of the controversy of the past concerning the price to be paid for the steam was due to an antagonistic and overreaching policy upon the part of the committees concerned. The sanitary committee as vendors were frequently at fault in seeking to obtain too much, while the electricity committee as purchasers were often anxious to drive too hard a bargain, with the result that when a settlement was effected some feeling of dissatisfaction still remained.

There is now a general consensus of opinion that the power from refuse should, if at all practicable, be fully utilised, and the location of the electricity works is usually so favourable from the cartage point of view that it claims very serious consideration.

In a paper read before the Aberdeen Conference of Cleansing Superintendents on April 15, 1911, Mr F. W. Brookman of Rochdale, who has done much to demonstrate the fuel value of refuse, expressed the following opinion:—

"You may take it that 20,000 tons of refuse per annum will run a tram service requiring 1,500,000 units approximately. As to what the cleansing department should have for such energy will depend upon which department pays for and supervises the generating plant, but while I think the cleansing department should be paid a reasonable price for the power they turn out, rather than not have the power used I would personally hand it over without payment, on the democratic principle that it is for the general good, and while my department would be something out of pocket as a department, the corporation as a whole would gain, in that the power was put to a good and useful purpose."

So long as there is departmental rivalry it will not be easy to work on such lines as Mr Brookman indicates. At the same time it is impossible to ignore the fact that inter-departmental payments do not affect the ratepayer in any way; the *net* result is precisely the same in the long run if there is no payment at all as between the two departments. The main point is to ensure the use of the power.

In an inaugural address to the Leeds Section of the Institution of Electrical Engineers on November 17, 1904, Mr Walter Emmott, M.I.E.E., President, said:—

"As there is now no difficulty in getting an output of 45 kw. per ton of refuse of even only a fair average quality, it is evident that the return is worthy of consideration, as representing a certain monetary value which would otherwise be expended in coal, and by this means helps a municipality along with its electricity undertaking, and also

enables it to get rid of the refuse. . . . One thing is certain, that by combining the two departments the municipality obtains the best possible arrangement for efficiently disposing of its refuse, and any electricity obtained is an asset which would otherwise be lost unless some other means were found for utilising the steam."

Mr J. A. Robertson, Burgh Electrical Engineer of Greenock, in a paper[1] contributed to the Glasgow Section of the Institution of Electrical Engineers on February 8, 1909, very clearly set forth those conditions which should obtain in order to ensure the financial success of a combined undertaking, and a careful study of the data set forth in Table IV. will serve to show the soundness of Mr Robertson's contentions when he says:—

"In order to justify the combination in most cases, the whole or nearly the whole of the available heat must be utilised; it follows that a continuous load must be available at the power station. *In residential districts where current is used chiefly for lighting purposes, it is questionable if any benefit is obtained by linking up the two undertakings,* and in many cases it will be found that the disappointing results obtained are due to an imperfect consideration of this condition. Each case requires to be considered on its merits with due regard to local conditions, such as the price of fuel, the quality of the refuse, and especially the nature of the demand on the power station. Generally speaking, it may be said that in those industrial districts where a power load exists, or where a tramway supply forms part of the output of the station, the refuse destructor and electricity works can be combined and operated with financial benefit to the community."

Having in mind that the vexed question of payment for the steam is no longer the subject of serious controversy, no useful purpose can be served by a discussion of the various bases for payment which have from time to time been suggested.

Perhaps the most equitable basis is that adopted at the combined destructor and electricity works of the Metropolitan Borough of Hackney. Here the whole of the refuse is weighed and the feed water for the boilers is measured; the payment is based upon the actual fuel cost in connection with the coal-fired boilers. The amount paid for steam supplied from the destructor represents the actual saving effected in the coal account of the electricity department.

Under these conditions, if the price per ton for coal under the annual contract falls, the revenue for steam decreases proportionately. On the

[1] "Electricity Works and Refuse Destructors," by Mr J. A. Robertson; see *Proceedings of the Institution of Electrical Engineers* (Glasgow Section), 1909.

contrary, if the price per ton of coal rises, the revenue from the destructor steam increases proportionately.

The following Table V. is a record of the work done at Hackney during the six years ending March 31, 1908. During that year the amount paid by the electricity department for steam supplied was £2288, 1s. 3d.

TABLE V.

(1) Year.	(2) Weight of Refuse Destroyed.	(3) Largest Quantity in One Day.	(4) Smallest Quantity in One Day.	(5) Average Weight Destroyed Daily.	(6) Total Water Evaporated.	(7) Lbs. Water Evaporated per Pound of Refuse Destroyed.	(8) Steam Utilised by Electricity Department.
	Tons.	Tons.	Tons.	Tons.	Lbs.		Lbs.
1902-3	34,006	186	41	120	41,411,970	0·543	41,411,970
1903-4	39,175	189	38	128	45,628,769	0·519	45,628,769
1904-5	37,554	190	35	122	62,075,720	0·738	62,075,720
1905-6	38,048	195	55	124	66,548,965	0·781	66,548,965
1906-7	37,956	191	31	124·5	68,147,485	0·801	68,147,485
1907-8	38,308	187·5	51	124·4	73,464,675	0·856	73,464,675

During the year 1909 nearly nine million Board of Trade units were generated from refuse in Liverpool at five combined works, the energy being used for electric traction. The work done in connection with each installation will be seen from the following records:—

Destructor.	Tons of Refuse Destroyed.	Board of Trade Units Generated.
Charters Street	58,172	3,044,469
Laverock Bank	31,090	2,069,598
St Domingo	37,792	2,028,766
Smithsdown Road	25,444	1,383,783
Garston	7,117	370,821
Total .	159,615	8,897,437

The revenue from the sale of current is between £7000 and £8000 per annum on the basis of ·2d. per unit.

At the Eastcroft (Nottingham) combined works during the same period the following results were obtained:—

Weight of refuse destroyed . .	34,921 tons.
Water evaporated	9,861,000 gallons.
Board of Trade units generated .	1,195,279.

The results of the first year's operation of the combined undertaking at Greenock will be seen in the following table:—

TABLE VI.—GREENOCK DESTRUCTOR AND ELECTRICITY WORKS.

REVENUE ACCOUNT.

Expenditure.

	£	Per Ton. s.	d.
Labour—			
Operating destructor	936	1	$1\frac{1}{4}$
Treatment of residue	134	0	2
Repairs—			
(*a*) Buildings	40	0	$2\frac{1}{4}$
(*b*) Plant	120		
Disposal of unsaleable residue	135	0	2
Power and light	330	0	$4\frac{1}{2}$
Rates, taxes, insurance	83	0	$1\frac{1}{4}$
Management	65	0	$0\frac{3}{4}$
Total	1,843	2	2

Credit.

	£	s.	d.
Sale of steam	1,665		
Sale of clinker	65		
	1730	2	$0\frac{1}{4}$
Balance to net revenue account	113	0	$1\frac{3}{4}$
Total	1,843	2	2

Net Revenue Account.

	£	s.	d.
Interest on £19,800 at $3\frac{1}{2}$ per cent.	696	0	$9\frac{3}{4}$
Sinking fund $\frac{1}{30}$th of capital	663	0	$9\frac{1}{4}$
Balance from revenue account	113	0	$1\frac{3}{4}$
Net cost of disposal	1,472	1	$8\frac{3}{4}$

Technical Records.

Tons of refuse destroyed	16,995
Units produced from destructor steam	1,142,064
Units used for power and light	132,006
Units generated per ton	67·2
Total clinker produced (tons)	5,338
Total clinker sold (do.)	1,286

The chart fig. 22 illustrates the weight of refuse delivered and the Board of Trade units generated per ton of refuse destroyed throughout the same year 1908–9.

Table VII. is of more than usual interest, inasmuch as the comparative results with coal and refuse over a period of several months are clearly set forth. It may, however, with fairness be observed that the refuse at Pontypridd is exceedingly good.

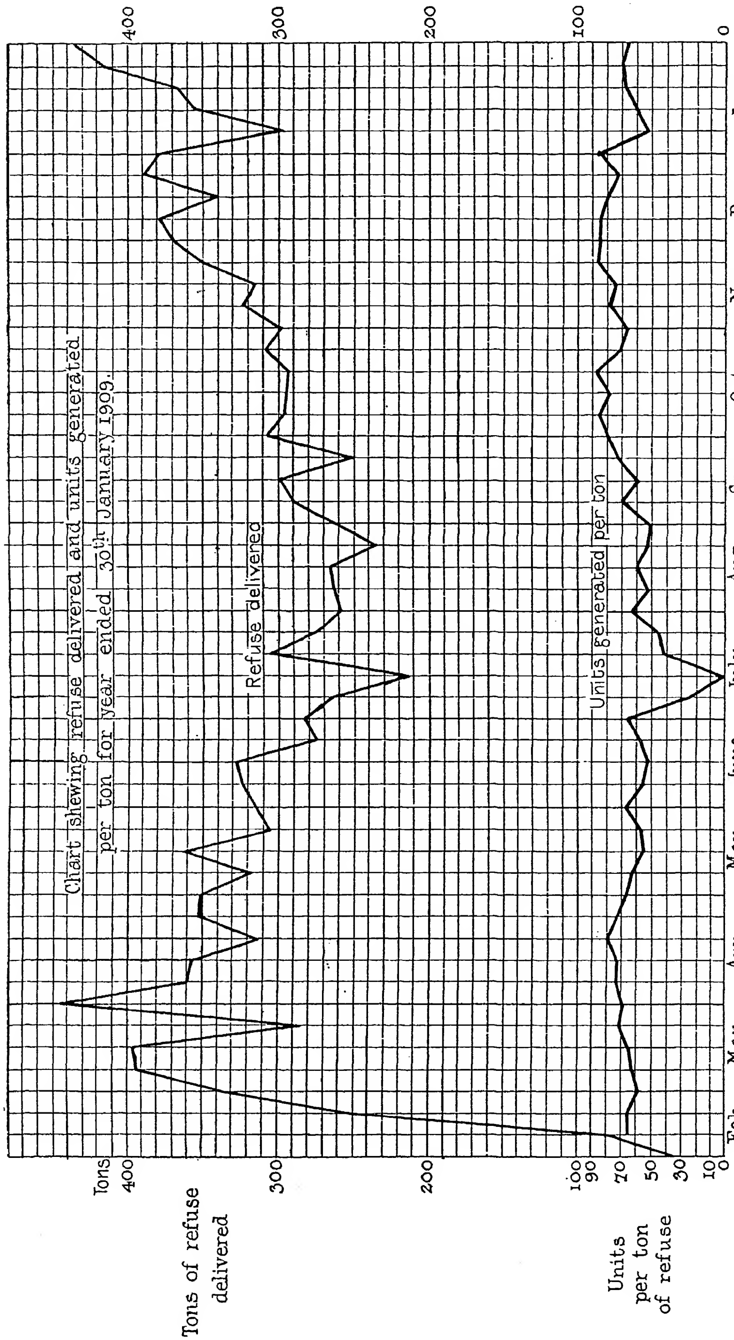

FIG. 22.—Refuse Consumption and Electrical Output Diagram. Greenock combined Destructor and Electricity Works.

TABLE VII.—URBAN DISTRICT COUNCIL OF PONTYPRIDD.

DESTRUCTOR WORKS AND ELECTRICITY GENERATING STATION.

Comparative Statement of Coal and Refuse and Units generated in the latter half of 1908 and 1909 respectively.

Month ending	Refuse Tons.	Coal Tons.	From Refuse Units.	From Coal Units.	Total Units.	Units per Ton Refuse.	Units per Ton Coal.
1908							
Sept. 9	Refuse destructor not yet in operation.	219	...	77,658	77,658	...	355
Oct. 7		225	...	84,300	84,300	...	375
Nov. 4		275	...	92,567	92,567	...	336
Dec. 2		289	...	91,149	91,949	...	318
Dec. 30		290	...	103,611	103,611	...	357
Jan. 27/09		269	...	100,955	100,955	...	375
		1567		551,040	551,040		Av. 352
1909							
Sept. 8	553	54	62,302	19,008	81,310	113	352
Oct. 6	660	66	65,622	23,232	88,854	99	,,
Nov. 3	782	86	68,185	30,272	98,457	87	,,
Dec. 1	776	57	85,894	20,064	105,958	110	,,
Dec. 29	863	56	95,304	19,712	115,016	110	,,
Jan. 26/10	917	46	98·966	16,192	115,158	108	,
	4551	365	476,273	128,482	604,753	*Av. 104·5	Av. 352

* This does not take into account steam wasted in blowing off. Total works costs reduced from 1·10 to ·82 per unit—£1500 per annum on 100,000 units per month (four weeks). Value of coal 13·5 shillings per ton—(2240 lbs.).

What may be done in connection with a small combined undertaking having a good power load is shown in the following figures, covering one complete year, and the Table VIII. covering one month's working:—

FLEETWOOD URBAN DISTRICT COUNCIL ELECTRICITY AND DESTRUCTOR WORKS.

Results for one year ending January 17, 1910.

Total refuse destroyed	3,362 tons.
,, B. of T. units generated from refuse . .	244,212 units.
Average[1] ,, ,, ,, per ton of refuse destroyed	73 ,,
Average evaporation per pound of refuse destroyed	1·4

[1] The average steam consumption per unit generated was 43 lbs.

TABLE VIII.—FLEETWOOD URBAN DISTRICT COUNCIL ELECTRICITY AND DESTRUCTOR WORKS.

Month of November 1909.

	Week Ending Sunday 7th.	Week Ending Sunday 14th.	Week Ending Sunday 21st.	Week Ending Sunday 28th.	Total.
Units generated (per meter)	10,404	10,147	10,512	11,311	42,374
,, used at works	1,252	1,207	1,270	1,300	5,029
,, sold. Private consumers	7,240	6,991	7,235	7,880	29,346
,, sold. Public lighting	1,351	1,346	1,362	1,325	5,384
Total units accounted for	9,843	9,544	9,867	10,505	39,759
Total units not accounted for	561	603	645	806	2,615
Percentage to generated	5·37%	5·9%	6·15%	6·2%	6·2%
	Tons cwts.	Tons cwts.	Tons cwts.	Tons cwts.	Tons cwts.
Fuel. Stock brought forward	11 18	14 9	13 13	12 3	
Coal received	17 18	17 15	16 16	19 3	71 12
Total stock	29 16	33 4	30 9	31 6	
Coal used	15 7	19 11	18 6	18 3	71 7
Carried forward	14 9	13 13	12 3	13 3	
No. of loads of refuse destroyed	68	67	67	68	270
Units generated (per meter)	10,404	10,147	10,512	11,311	42,374
,, from coal at units per ton	3,837	4,900	4,575	4,505	17,800
,, *from refuse*	6,567	5,274	5,937	6,811	24,574
,, *per load of refuse* *	96·5	79	89	100	91
,, per ton of coal and refuse	680	520	600	630	595
Lbs. of coal per unit generated	3·3	4·3	3·75	3·55	3·75
Cost of coal	£10 11	£13 8 10	£12 0 7	£12 9 6	£48 10
Cost of coal per unit generated	0·24d.	0·32d.	0·275d.	0·265d.	0·275d.
Total water evaporated (per meter)	43,500	42,600	45,500	50,000	181,600
Total water evaporated per unit generated	42·0	42·0	43·1	44·0	43·0
Make-up water to condenser (per meter)	6,000	8,000	8,000	6,000	28,000
Percentage to total evaporated	13·8%	18·8%	17·6%	12·0%	15·5%

* A load equals approximately one ton.

Among the most successful of the small combined undertakings are those of Bury St Edmunds and Cambuslang; at the former works, during the first eight months after the erection of the destructor, 1500

tons of refuse were destroyed, effecting a saving of 380 tons of steam coal at 19s. 11d. per ton d/d, a very creditable record for a small station.

At Cambuslang, during the year ending May 15, 1909, the units generated were 117,845, of which 5891 units only were generated from coal, the total cost of coal for the year being £24 only.

The following Table IX., covering twelve weeks' working, shows that during half of this period no coal was burned, and it is worthy of note that a good proportion of the coal which is burned at these works is wasted in getting up steam from cold with the coal-fired boiler. The wages cost per ton of refuse destroyed includes not only the charging and clinkering, but also the weighing of the refuse.

TABLE IX.—CAMBUSLANG (LANARK COUNTY COUNCIL) COMBINED DESTRUCTOR AND ELECTRICITY WORKS.

Week Ending.	Total Units Generated.	Units Generated from Refuse.	Units Generated from Coal.	Refuse Destroyed.	Coal Used.	Wages Cost per Ton of Refuse Destroyed.	Cost of Coal.
				T. C. Q.	T. C.	s. d.	£ s.
7/12/07	3,261	3,114	147	93 2 2	1 2	1 1	0 11
14/12/07	3,409	2,956	453	103 4 1	2 14	0 11¾	1 7
21/12/07	3,591	3,315	276	107 6 3	2 2	0 11½	1 2
28/12/07	3,531	3,531	None	90 6 2	None	1 1¼	...
4/ 1/08	3,622	3,107	515	86 8 1	2 8	1 2	1 4
11/ 1/08	3,441	3,365	76	121 13 0	0 12	0 9¾	0 6
18/ 1/08	3,283	3,283	None	103 0 0	None	0 11¾	...
25/ 1/08	3,176	2,763	413	106 1 3	2 8	0 11½	1 4
1/ 2/08	2,965	2,965	None	101 3 2	None	1 0	...
8/ 2/08	2,797	2,797	None	96 9 0	None	1 0½	...
15/ 2/08	2,667	2,340	327	99 5 2	2 2	1 0	1 1
22/ 2/08	2,468	2,468	None	100 16 0	None	1 0	...
29/ 2/08	2,350	2,350	None	105 15 1	None	0 11½	...
Total	40,561	38,354	2,207	1,318 12 1	13 8	1s. per ton Average.	6 15

The combined destructor and electric tramways station of the Corporation of Preston is an excellent example of a well-designed and successful works.

The average weight of refuse destroyed daily is 72 tons, and over a period of six months an average evaporation of 1·4 pounds of water per pound of refuse has been obtained.

The weekly output of current averages about 30,000 units, and the revenue derived from the same is now about £1150 per annum.

Table IV., herein included, brings together a great deal of very interesting data concerning combined works. The foregoing results are

separately tabulated, because in each case the figures cover a considerable period, and are not test figures, while the works in question are representative examples in various parts of Great Britain.

Not many years since, when the combined electricity and destructor works was the subject of much controversy, it was asked why, if the combination is so satisfactory, does it fail to attract private enterprise? Further, it was observed that not only do electricity companies leave the field to municipalities, but in towns where the electricity supply is in the hands of a company they decline to purchase either steam or electrical energy.

The following extracts from an article[1] contributed by the author to *Electrical Investments,* in 1905, discusses some of the difficulties then existing, and to some extent explains the attitude of electricity companies towards combined undertakings at that time:—

"If you would have value for money avoid the cheap installation as you would a pestilence; pay a fair price, and bind the maker down to definite guarantees under working conditions. Do not offer to pay him in paper, but rather on that equitable basis generally recognised by municipal authorities. It is impossible to run a destructor business on a paper revenue. To offer payment partly or entirely in paper will never tempt the best makers to tender; those who are doing a live business and have their capital employed cannot afford to take payment in paper, and the sooner this is recognised by companies the better for them.

"If the destructor maker is offering an efficient and fully guaranteed plant at a fair price, it is unreasonable to expect him to take a share in the speculation of his client. It is impossible to conduct a modern engineering business on this speculative basis, and every manufacturer would do well to resist the introduction of such a system to the best of his ability.

"Why are so many municipal authorities now operating combined works unable to show a net profit on the refuse disposal side? Having in mind that those conditions already discussed for the most part do not obtain in the case of a municipal authority, then there must obviously be other reasons why the record of combined municipal undertakings is not more satisfactory than is shown by the published returns.

"In the first place, it may be observed that in the case of nine out of every ten combined works, the accounts are hopelessly mixed up. Instead of presenting separate accounts for the two works, clearly showing where the loss is incurred, if loss there be, we have a maze of figures un-

[1] "Are Refuse Destructors Financially Reproductive?" by W. Francis Goodrich, *Electrical Investments*, vol. v., No. 224, Aug. 9, 1905.

intelligible to the average citizen, and positively bewildering even to the expert statistician. Generally speaking, there is no serious attempt to render lucid and separate accounts; and when a net deficit is shown on the combined undertaking, the ingenious electrical engineer invariably suggests that it is due to the combination of the refuse destructor. It is perhaps but natural that this explanation should be offered by the electrical engineer, but the fact remains that little or no evidence is ever forthcoming in support of such a statement.

"As a result of much investigation, the writer is of opinion that in the muddled accounts the sanitary undertaking is frequently dealt with most unfairly. In many cases, if the figures were presented separately, there is no doubt that the destructor accounts would show a net profit, whereas the net deficit is now saddled upon the combined undertaking. It is quite true that in some cases an exorbitant rate of payment is demanded for the steam supplied to the electricity department, but for every one example of this kind there are two cases where steam is not paid for at anything like a reasonable rate.

"Among electrical engineers the opinion is freely held and expressed that their department should 'make something out of the destructor.' Nothing could be more absurd. Departmentally, they have no right whatever to make a profit at its expense; and, always providing that a useful amount of steam is available when wanted at a well-maintained pressure, then steam from refuse is surely of equal value to that obtained from coal. As the writer has observed many times, much of the objection upon the part of electrical engineers to the combination of destructors with electricity works would disappear if municipal authorities would only grant some extra remuneration to their servants for the extra work which thereby devolves upon them.

"When a refuse destructor is operated apart from an electricity works, a superintendent is invariably engaged. Why, then, fasten this work upon the electrical engineer without any extra remuneration? It is not fair treatment, to say the least of it, and with not a few engineers it is a grievance silently cherished, but nevertheless very material. Unlike Oliver Twist, they do not ask for more, but they show their resentment by discounting the value of the combination generally, when the real crux of the matter is that the combination is of no value to *them* from the standpoint of personal remuneration. Perhaps one of the most serious mistakes made by municipal authorities in the erection of combined works is the provision of needlessly elaborate and expensive buildings and chimneys. In pandering to the æsthetic taste many works are seriously over-capitalised, frequently fully twice as much money being sunk in

buildings and chimneys as is necessary. To thus increase the annual capital charges is a very serious matter indeed, as many municipal electrical engineers have found out; the extra annual repayment of a few hundred pounds will often cripple a station for some few years. This is a blunder which is always carefully avoided by the electric light and power company, and for this reason they should obviously be in a better position to show a net surplus from the beginning.

"In order to ensure that a destructor shall be a financially reproductive undertaking certain conditions must obtain, which we will briefly discuss:—

"(1) The capital expenditure on the plant and its accessories must be kept as low as possible, consistent with the best materials and workmanship and the highest efficiency.

"(2) The cost of the building and chimney must be kept within reasonable limits, always bearing in mind that the main requirements are that the buildings and chimney shall be substantial and well adapted for their purpose. Fine architectural effect is all very well, but it does not spell either surplus or dividend.

"(3) The available power must be fully utilised.

"(4) In the case of a station operated by a company, the municipal authority should not only deliver the refuse free of charge, but, seeing that it is finally disposed of on a central site at the minimum of cartage cost to the authority, they should certainly pay the company a nominal sum (say 9d.) per ton of refuse destroyed.

"(5) Where a destructor is operated by a company all residuals should be the property of the company, and, so far as is practicable, the authorities should purchase and utilise such residuals."

While further reasons might have been adduced to account for the attitude of electricity companies, time has served to show that if private enterprise was not then attracted because it was felt that the combination was unprofitable, this feeling no longer exists.

Not only are electricity companies now operating destructors to their own profit, but other companies are purchasing electrical energy from municipal works both at home and abroad.

The destructors at St Albans and Hertford, operated by the North Metropolitan Electric Power Supply Co., Ltd., while presumably being profitable to the company, has the effect of enabling these towns to dispose of their refuse very cheaply. Whether it is a wise policy for a municipality to delegate a sanitary duty to a company is a question upon which there is much difference of opinion.

The combined installation at Hertford is unusually interesting; with

an average of from 7 to 8 tons of refuse daily, the electrical output averages about 60 Board of Trade units per ton of refuse destroyed.

In order to obtain the maximum advantage from the refuse, it is only burned when the steam can be fully utilised, *i.e.* between 3 p.m. and 10 p.m. So valuable is the refuse regarded as a fuel, although the quality is not above the average, that no waste is permitted under any circumstances.

The Corporation of Hertford deliver the refuse to the works, and pay the company £150 per annum for disposing of the same, which is equal to about 1s. 3d. per ton, to which must be added the value of the steam and the clinker.

The great and rapid increase in the number of combined undertakings, their record, and the fact that private enterprise has been attracted, furnish eloquent testimony as to the practical value of the combination. That the ratepayer does benefit is no longer a debatable point. The gain in sanitary efficiency, minimum cartage cost, and in the utilisation of the bye-products is unquestionable, and the fact that it is no longer the subject of serious controversy is an all-sufficient answer to the pessimist.

At the same time it cannot be too strongly urged that those who may be responsible for the combined undertakings of the future should carefully study past history, and that every case should be considered on its merits. The statistics which are included in Table IV. clearly indicate where mistakes have been made in the past, the results of which in some cases are still evident. It would be invidious to extract and separately tabulate these works; it will suffice to say that there are a number of combined undertakings the record of which conclusively supports the arguments advanced by Mr J. A. Robertson.

CHAPTER VI.

REFUSE DESTRUCTORS IN THE UNITED KINGDOM.

MOST of the destructor installations in the United Kingdom have been fully described and illustrated either in the technical press or in previous works on refuse disposal.

To avoid repetition, and to bring together in useful form the principal data in connection with the whole of the installations in the British Isles, the author prepared the accompanying Table X. and the supplementary Tables III. and IV. (see pages 51 and 54).

Some Representative Installations.—In briefly describing and illustrating a few of the more recent installations it will be noted that examples of three classes have been selected:—

(1) Destructors combined with electricity works,

(2) Destructors combined with sewage works, and

(3) Destructors which do not provide steam other than that utilised in the operation of the plant.

ST ALBANS.

The destructor here is of the "Heenan" front-fed type, and unlike most destructor undertakings, is owned and operated by a company.

By arrangement with the St Albans Corporation, the destructor was erected for the North Metropolitan Electric Power Supply Company Limited in conjunction with a generating station, the corporation delivering the refuse to the works.

The destructor consists of two 3-grate units with combustion chambers, 2 Babcock & Wilcox boilers of about 2000 sq. ft. of heating surface, each fitted with Foster superheaters. Forced draught is provided by a fan which is arranged for driving either by means of the usual high speed engine or a motor of the variable speed type, with shunt regulator. Regenerators are provided for heating the air for combustion. The chimney is 130 ft. in height, and has an internal diameter at the top of 5 ft. 6 in.

Stourbridge Urban trict Council
Taunton Corporatio
Walthamstow Urba trict Council
Watford Urban Di Council
Winchester Corpora
West Bridgford U District Council
Weymouth Corporat

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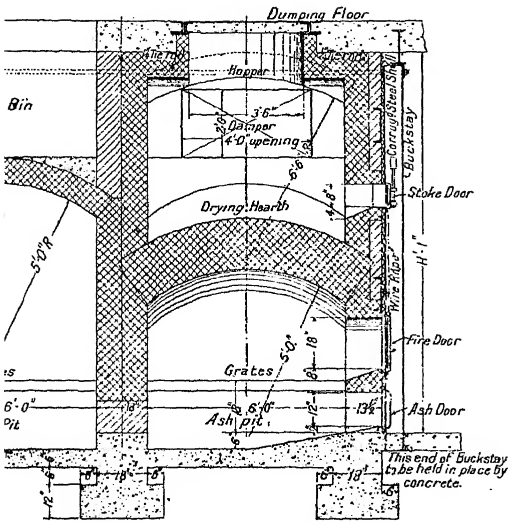

n A.A Section B.B.

From the cross-section and plan, see fig. 23, it will be seen that the building is arranged in three main bays. The destructor, boilers, and pumping plant occupy the rear bay, the centre accommodates the

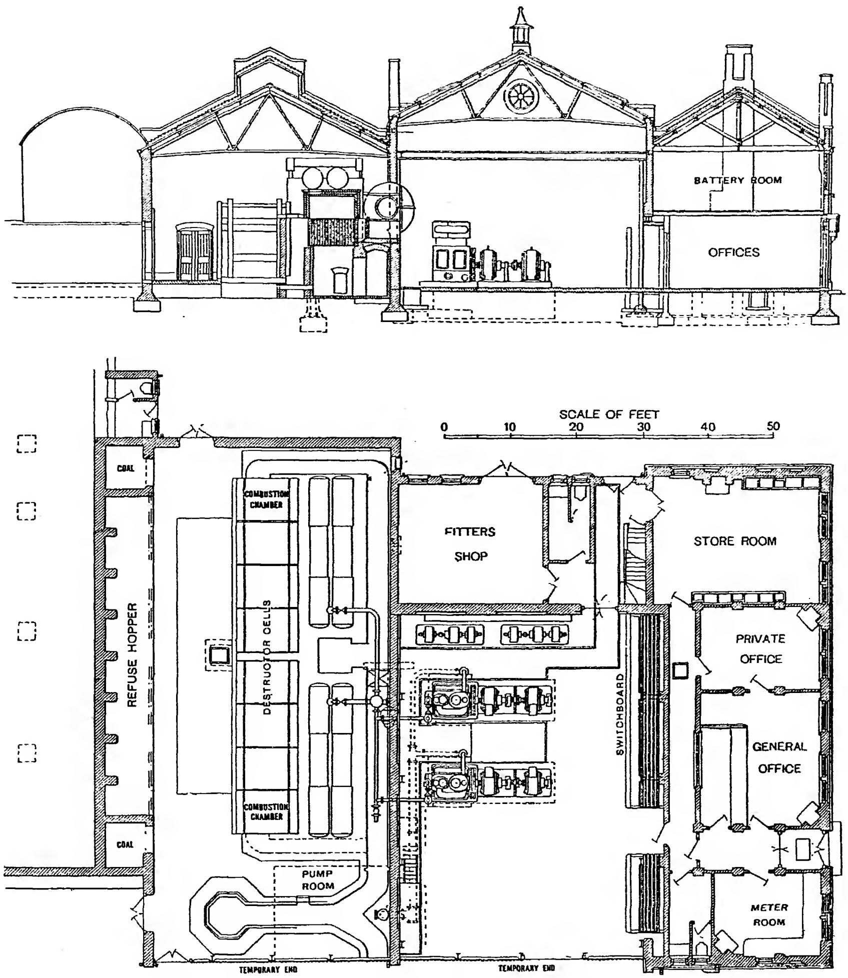

FIG. 23.—Heenan's Front-Fed Destructor at St Albans. Cross-section and plan.

generating sets and switch gear, while in the front portion are the battery-room, test-room, and offices. The generating plant consists of two 150 kw. sets.

Fig. 24 is a section and plan of the destructors and boilers, also showing the air heaters and fan.

The whole arrangement of the plant is unusually compact, and the destructor is an excellent example of a well-designed front-fed type.

FARNWORTH URBAN DISTRICT COUNCIL.

Erected in 1909, the destructor here is of the "Heenan" front-fed type, and is arranged to work in conjunction with the adjoining electricity works.

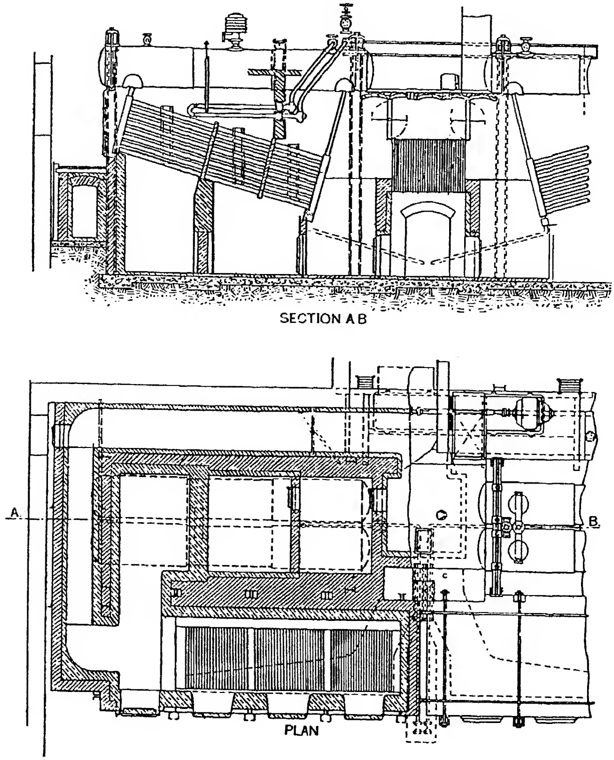

FIG. 24.—Heenan's Front-Fed Destructor at St Albans. Section and plan.

The destructor plant comprises 4 grates, the usual combustion chamber, and an offal hearth. The boiler is of the Lancashire type, 30 ft. long and 8 ft. 6 in. diameter; in the downtake a Foster superheater is fixed.

Forced draught is provided by steam-jet blowers, the air supply being heated in a regenerator. A Green's economiser is provided for the heating of the boiler feed water.

THE BURGH OF GREENOCK, N.B.

The installation at Greenock is of the Horsfall "tub-fed" type, and consists of six cells with three Babcock & Wilcox marine type boilers,

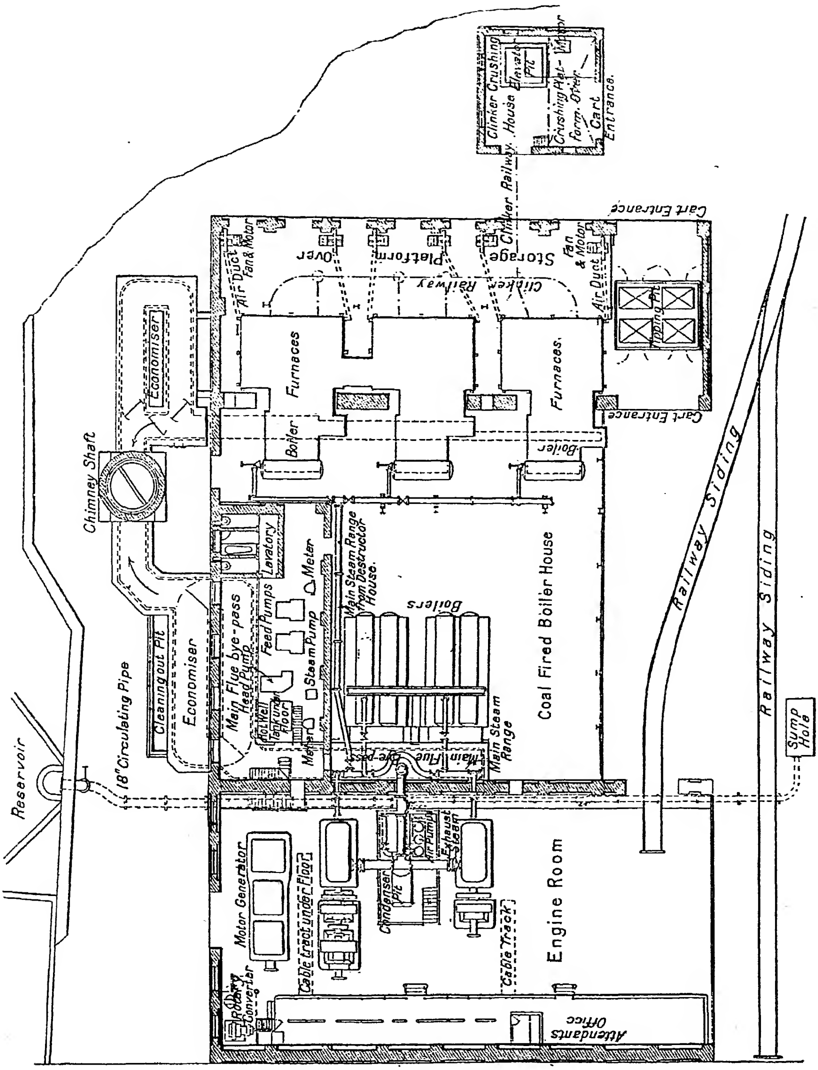

FIG. 25.—Greenock combined Destructor and Electricity Works. Plan.

arranged in three distinct units, each comprising two cells and one boiler.

The boilers, which work at 200 pounds pressure, are provided with superheaters, and the final temperature of the steam at the boilers is

550° Fahr. For the heating of the boiler feed water a large economiser is installed.

The steam is fully utilised in the generating station with which the destructor is combined. The general lay-out of the works is shown in fig. 25.

The average weight of refuse destroyed daily is about 57 tons, and the revenue from steam supplied during the first year of operation was £1665.

The total cost of the installation, including one half of the cost of the site and the chimney, the buildings, furnaces, plant, economiser, and a proportion of the steam and feed piping, was £19,800.

REDDITCH URBAN DISTRICT COUNCIL.

The destructor here is of the "Heenan" back-fed type, comprising one 3-grate unit with combustion chamber, a Babcock & Wilcox water-tube boiler having 1467 sq. ft. of heating surface, a regenerator, and fan-forced draught.

The steam is fully utilised in the adjoining electricity works; no charge is made for the steam, but the electricity department pay the wages of the firemen and also maintain the plant.

The average weight of refuse destroyed per annum is 2800 tons, the whole of the clinker is crushed and screened, 3s. 6d. per ton being obtained for the best; the rough clinker is sold at 1s. per ton, and is utilised for road foundations.

Prior to the erection of the destructor the refuse was carted to a tip two miles out of the town at a cost of 4s 1d. per ton: as it is now disposed of near the centre of the town a considerable saving in the cartage cost has been effected.

The total cost of the scheme was as follows:—

	£	s.	d.
Cells, combustion chamber, regenerator, boiler, fan, and engine	2480	0	0
Buildings and approach road	766	0	0
Clinker, crusher, elevator, and motor	185	0	0
Incidental expenses	57	0	0
	£3488	0	0

PRESTON CORPORATION.

One of the most complete and successful destructors supplying steam for electric traction purposes is that at Preston, which has the further distinction of being the largest front shovel-fed destructor in the world.

This installation, which comprises four units of 4 grates each, replaced a top-fed destructor which was erected eighteen years before. Fig. 26 is a view of the present plant in course of erection.

Each 4-grate unit is provided with a combustion chamber, the gases from which pass through a Lancashire boiler, 30 ft. by 8 ft. Two units are equipped with apparatus for lifting and transporting large carcases, which are dropped into the combustion chamber from above. Figs. 27 and 28 are views on top of the cells illustrating the handling of the carcase of a horse, and the removal of the top of the combustion chamber prior to dropping the carcase therein for cremation. For the

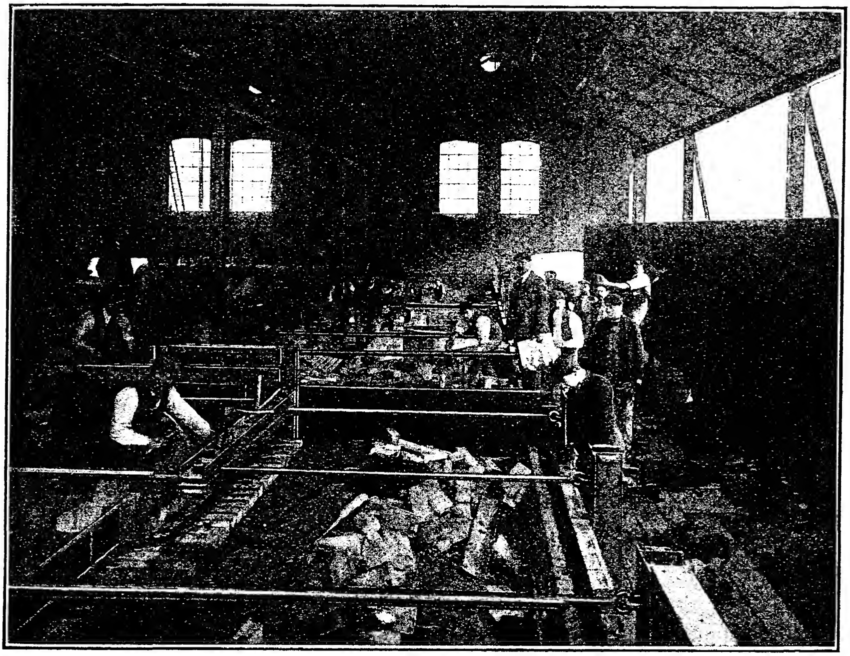

FIG. 26.—Preston Destructor, in course of erection.

disposal of offal without handling two units are provided with overhead gantries and special offal shoots.

Forced draught is provided by steam-jet blowers which work in conjunction with the regenerators, while for the heating of the feed water a large economiser is installed.

In the adjoining traction generating station are two horizontal cross-compound traction sets, which are used alternately, steam being provided from the destructor, which also provides steam for generating plant for lighting the car shed, workshops, destructor, stables, storeyard, etc.

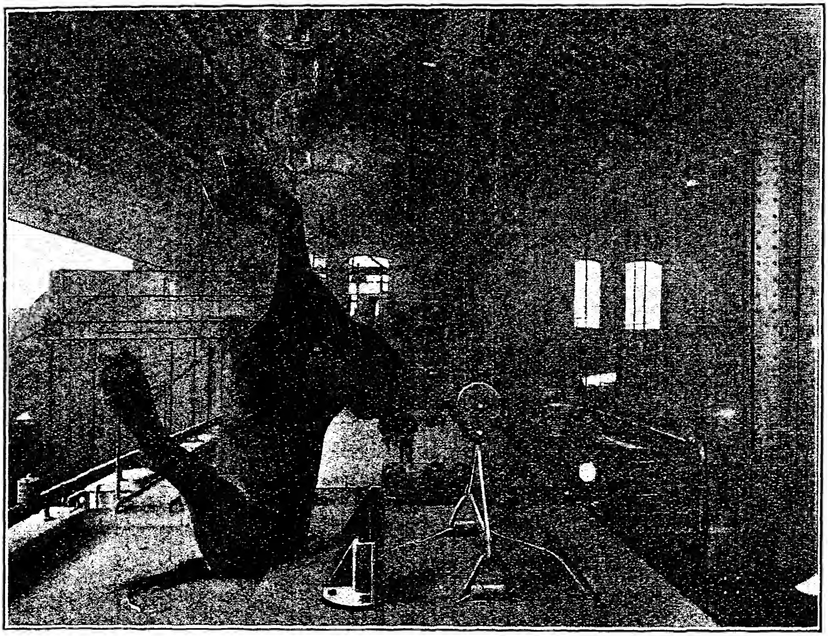

FIG. 27.—Preston Destructor, carcase cremation.

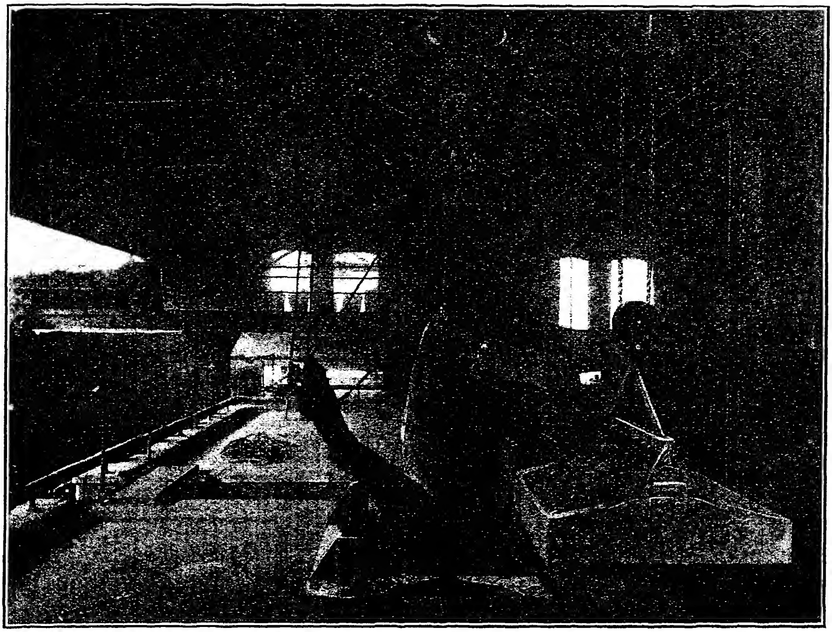

FIG. 28.—Preston Destructor, carcase cremation.

HODDESDON URBAN DISTRICT COUNCIL.

This installation is of special interest because it is one of the very few small destructors providing steam in conjunction with a sewage works.

The destructor, which is of the "Sterling" front-fed type, has a total grate area of 14 sq. ft., and is what is known as a 2-grate

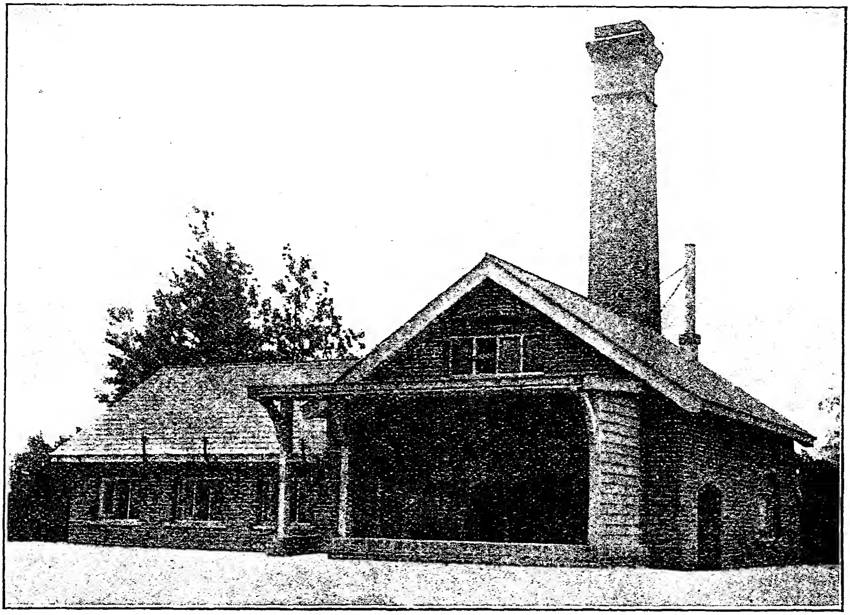

Fig. 29.—Hoddesdon Destructor, view of buildings and tipping platform.

destructor, although provided with a single large firing door. Between the furnace and the Babcock & Wilcox boiler is a combustion chamber.

Forced draught is provided by steam-jet blowers; owing to the small capacity of the plant a regenerator was not installed.

Fig. 29 illustrates the tipping platform, buildings, and the chimney, which is 40 ft. in height. Fig. 30 is a view of the destructor and boiler, while in fig. 31 the high-speed engines and the direct-coupled Gwynne centrifugal pumps are illustrated.

As will be observed, the whole installation, which was designed by Messrs John Taylor, Sons, & Santo Crimp, is very compact, and the destructor affords an interesting example of what may be done in a very small town with but 5 tons of refuse daily.

For use when the destructor is idle, for cleaning, a small Cochrane vertical boiler has been installed. The clinker is fully utilised in connection with the filter-beds at the works.

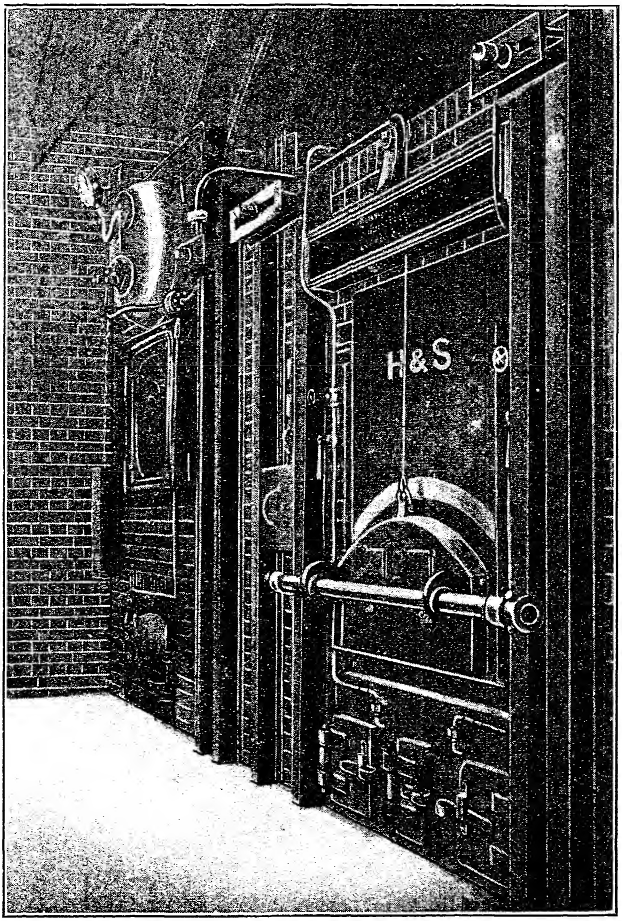

FIG. 30.—Hoddesdon Destructor, view of cells and boiler.

GUILDFORD CORPORATION.

The destructor here is of the top-fed, isolated-cell type, and was erected by Messrs Manlove, Alliott & Co., Ltd. The plant comprises four cells, each having 25 sq. ft. of grate area, with drying hearth.

The cells, with two Babcock & Wilcox water-tube boilers, are

arranged on the Wood & Brodie system, a boiler being set between two cells. Forced draught is provided by steam-jet blowers.

For the storage of the refuse, platforms are arranged at the rear of the charging openings at the top of the cells.

The chimney is 100 ft. in height, 4 ft. in diameter at the top, and octagonal in plan, lined throughout in firebrick.

The steam is fully utilised for the operation of air-compressing plant, for the supply of an extensive ejector system. In the compressor house,

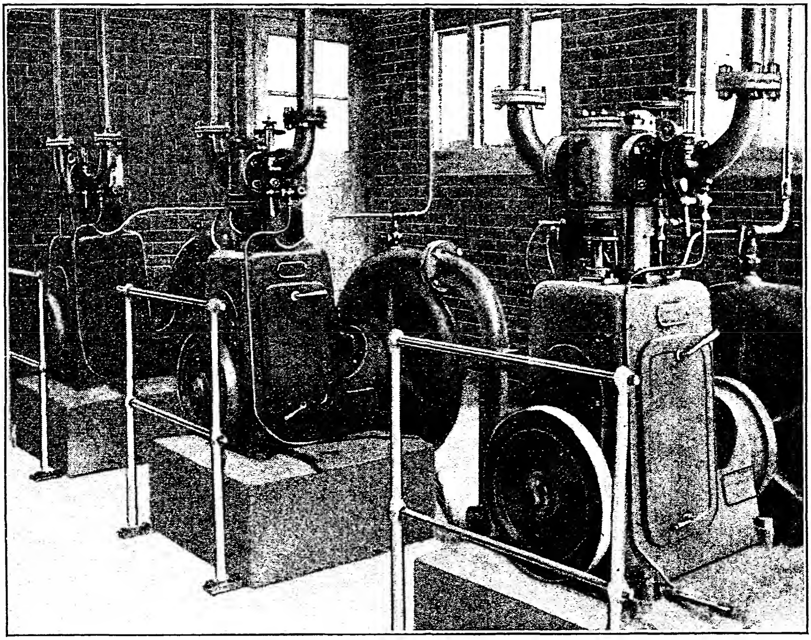

Fig. 31.—Hoddesdon Destructor, view of engines and centrifugal pumps.

which adjoins the destructor, are three sets of air compressors, each set consisting of two double-acting air compressors, driven by a cross-compound steam engine; in the same building are a surface condenser and steam-driven air and circulating pumps.

The compressed-air mains extend direct from the engine-room to eight ejector stations, at each of which the ejectors are in duplicate, varying in capacity from 1200 gallons to 50 gallons per minute.

For the lighting of the works a small high-speed Reavell engine with a Verity shunt wound dynamo is installed, steam being provided from the destructor boilers.

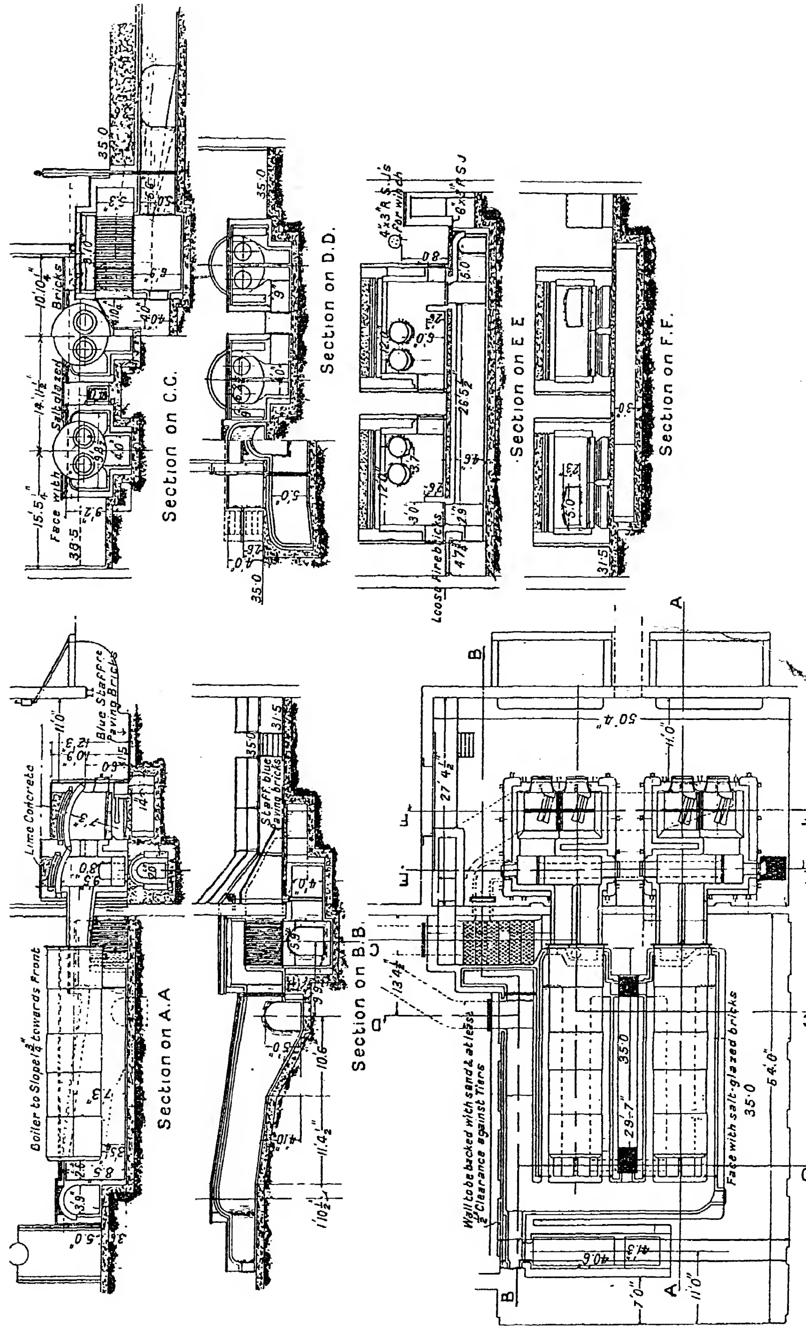

FIG. 32.—Meldrum's Front-F ructor at Twickenham. Plan and sections.

TWICKENHAM URBAN DISTRICT COUNCIL.

One of the most successful destructors combined with a sewage works is that at Twickenham, which is a typical Meldrum front-fed

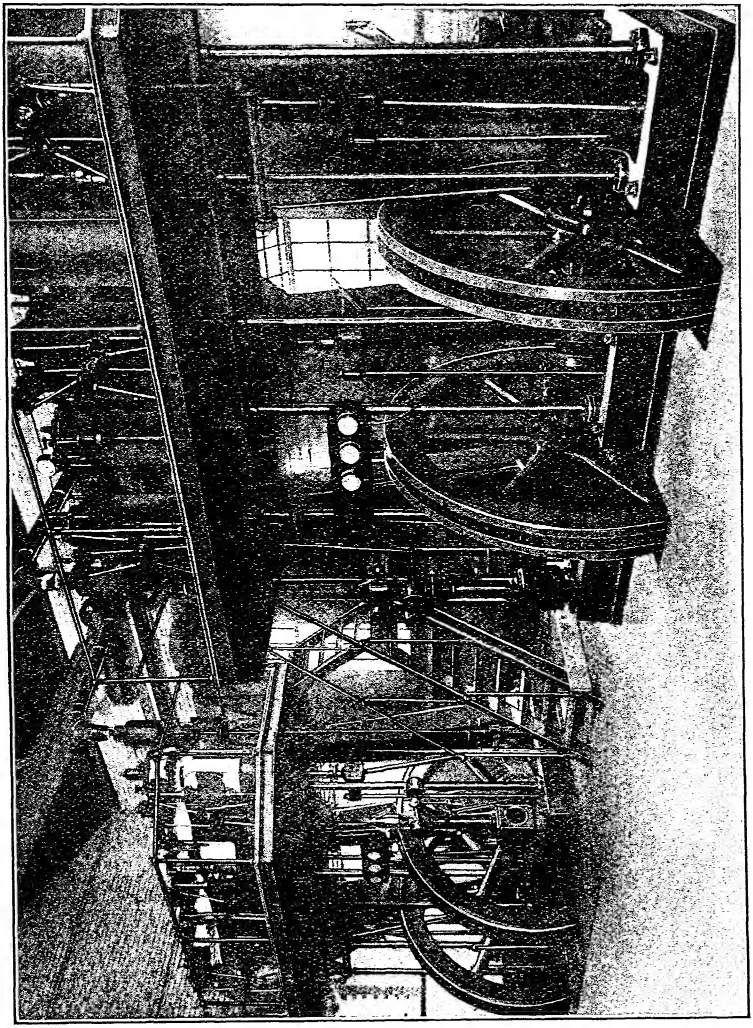

FIG. 33.—Pumping Engines, Twickenham Urban District Council combined Destructor and Sewage Works.

destructor. Fig. 32 is a plan of the installation, also showing the destructor details.

The destructor comprises two distinct units of 2 grates each, with combustion chambers, 2 Lancashire boilers, each 28 ft. long by 7 ft. 6 in.

diameter, with a regenerator common to both units. Forced draught is provided by steam-jet blowers.

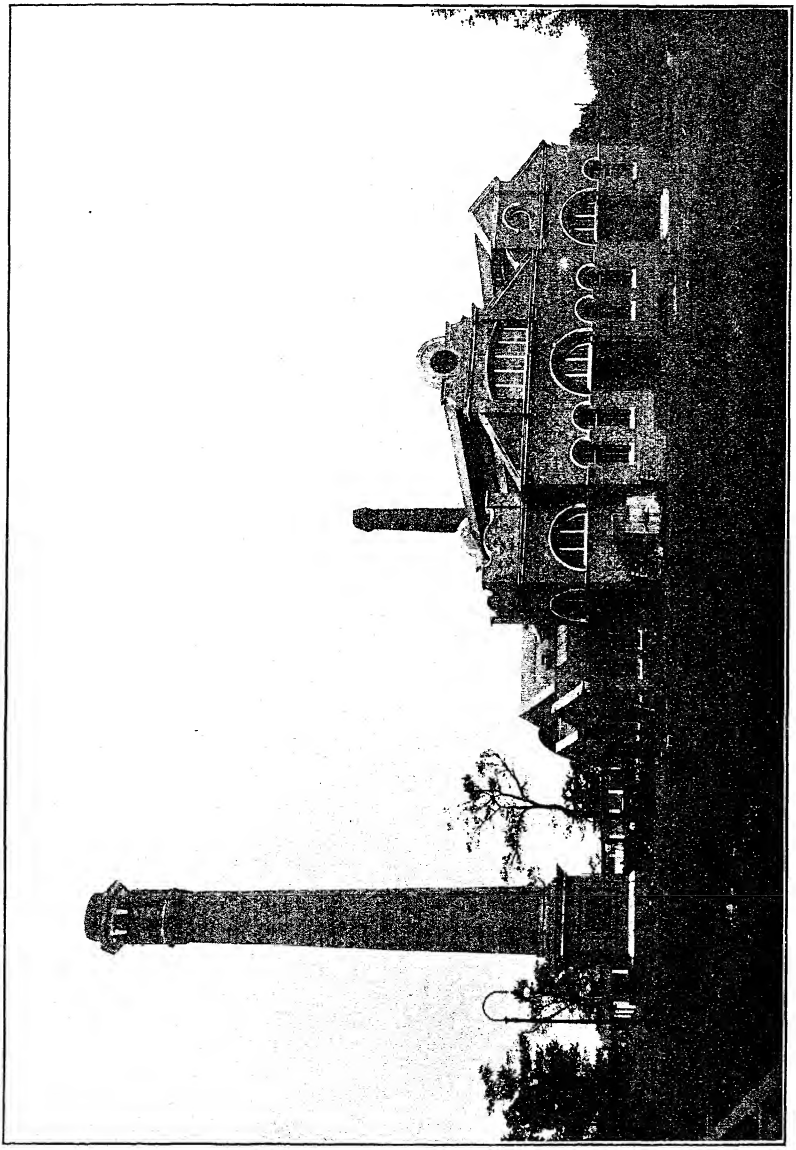

Fig. 34.—Twickenham Destructor, view of buildings and chimney.

Bye-pass flues are included, as also a supplementary coal-fired boiler of the Babcock & Wilcox type, which is only used in case of emergency.

During the five years prior to the erection of the destructor the average annual coal consumption was 1000 tons, costing £800, and for the last year out of the five years, viz. 1906, 1220 tons of coal were burned, costing £976.

The pumping plant in the adjoining sewage pumping station comprises two triple-expansion vertical condensing engines, having a capacity of 6,000,000 gallons per day. The auxiliary plant consists of sludge

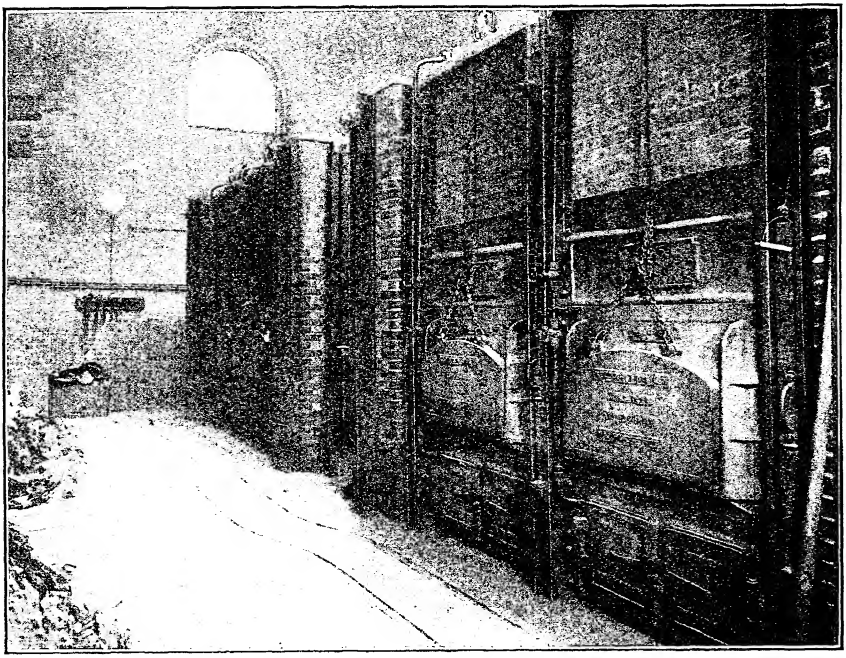

Fig. 35.—Twickenham Urban District Council combined Destructor and Sewage Works, view of cells.

ejectors, and also two 10-kw. generating sets, which supply current for the lighting of the council's Isolation Hospital at Whitton, rather more than a mile distant from the destructor and sewage works. Fig. 33 is a view of the triple-expansion vertical pumping engines.

Since the erection of the destructor, and during the year ending March 31, 1909, 5229 tons of refuse were burned, and 40 tons of coal only, a remarkably fine result at a works where the pumping load is exceptionally heavy.

Fig. 34 is an external view of the combined sewage and destructor works at Twickenham, while fig. 35 shows the cells from the charging floor.

GAINSBOROUGH URBAN DISTRICT COUNCIL.

The installation at Gainsborough is a typical Meldrum back-fed plant, differing only from the usual Meldrum type in the omission of a regenerator.

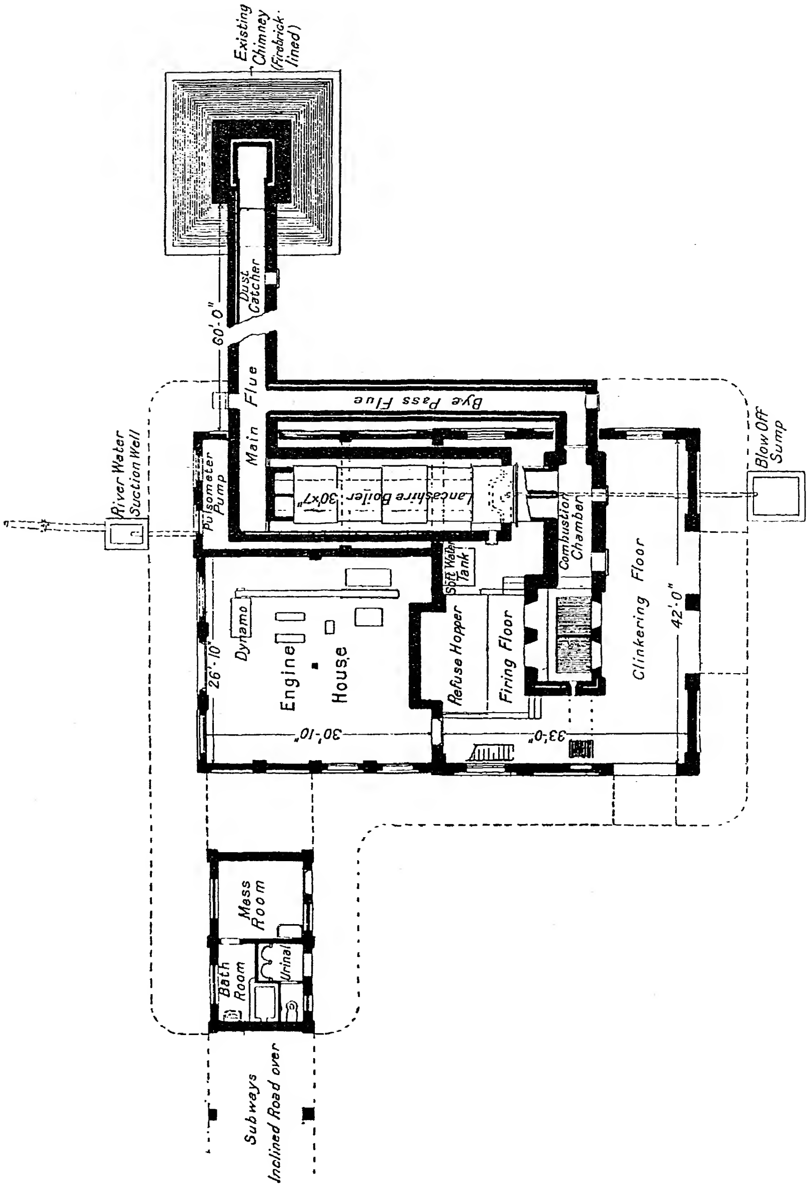

FIG. 36.—Meldrum's Back-Fed Destructor at Gainsborough. Plan.

The general lay out of the plant is illustrated in plans in fig. 36. Briefly described the destructor consists of two grates, each having an area of 25 sq. ft., with drying hearths, and a spacious combustion chamber. The boiler is of the Lancashire type, 30 ft. long by 7 ft. in diameter, for a working pressure of 120 lbs.; a bye-pass flue is provided owing to the impossibility of fully utilising the steam.

The chimney, which was erected in 1894 for a brickworks, is 110 ft. in height, and was lined with firebrick and reduced in area to be suitable for destructor purposes.

The buildings are in red local bricks with stone dressings and white brick panels. The inclined approach roadway, which is 13 ft. wide, has a gradient of 1 in 18, the tipping platform being arranged over the engine-room in ferro concrete. The surface of the approach roadway is paved with Mountsorrel granite setts.

The guaranteed capacity of the destructor was 1 ton per hour; at the present time the daily collection of refuse is about 16 tons.

The cost of the complete scheme is given as £7000, the details being as follows:—

	£	s.	d.
3½ acres of land	1200	0	0
Buildings, inclined roadway, tipping platform, etc.	2000	0	0
Destructor, boiler setting, flues and chimney lining	1444	1	0
Boiler, water softener, storage tank, engine and dynamo	752	10	0
Miscellaneous items, including new refuse collection vehicles	406	0	0
Law costs and incidentals	97	9	0
4½ acres of land	1100	0	0
	£7000	0	0

SOUTHGATE URBAN DISTRICT COUNCIL.

Here the destructor was erected by Messrs Manlove, Alliott, & Co., Ltd., and consists of four cells of the isolated type, and one Babcock & Wilcox water-tube boiler.

For the storage and charging of the refuse Boulnois & Brodie's system is installed; this system is fully described and illustrated in another chapter. Forced draught is provided by means of steam-jet blowers.

The chimney is 140 ft. in height, and with the main flue was designed to ultimately serve eight or ten cells. At the base of the chimney a dust arrestor is provided. The site comprises about two acres, and the total cost of the scheme, including the site, was about £10,000.

THE BURGH OF CLYDEBANK, N.B.

Here the destructor is of the "Heenan" back-fed type, as erected in 1906; the plant comprised two 2-grate units, but was extended in 1910 to two 3-grate units.

A Lancashire boiler 22 ft. by 7 ft. 6 in. is connected to each unit, and, owing to the difficulty of utilising the power fully, bye-pass flues are provided.

Forced draught is provided by means of steam-driven fans, working in conjunction with regenerators for heating the air supply.

The buildings are in brick, of very substantial construction; the chimney is 125 ft. in height.

For the treatment of clinker a crushing and screening plant with a mortar mill is provided. The total cost of the whole plant, including land, was about £11,107.

DUBLIN CORPORATION.

The Dublin Corporation destructor is an excellent example of the Meldrum back-fed type, comprising two 4-grate destructors with combustion chambers, Babcock & Wilcox boilers, regenerators, and steam-jet blower forced draught.

This installation, which is illustrated in fig. 37, replaced an old top-fed destructor, and deals with an average of about 110 tons of refuse daily.

Among the interesting features of this installation is the use of the tramway track of the Dublin United Tramways for bringing refuse to the destructor. During the daytime refuse collected in outlying parts of the city is carted to the tram depôts, and after midnight, when the passenger service has ceased, the refuse is brought to the destructor in special tip wagons. This system has worked admirably, and the cost is said to be very low.

At the destructor works the steam available is only partially utilised, and much of the available power goes to waste.

PAIGNTON URBAN DISTRICT COUNCIL.

The destructor here was erected in 1909 for the Paignton Electric Light and Power Co., Ltd., and is of the "Sterling" back-fed type having two grates.

A Cornish boiler 10 ft. by 5 ft. is installed, but as steam is only

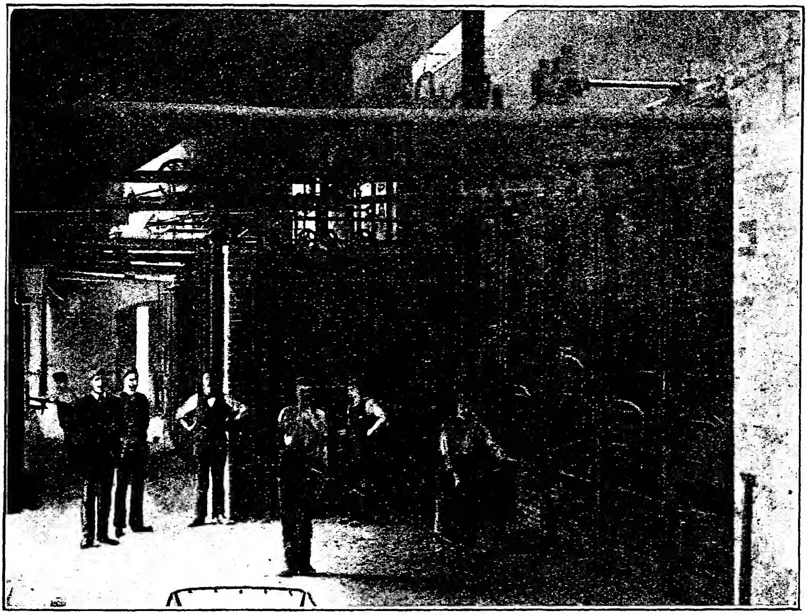

FIG. 37.—Dublin Corporation Destructor, view of cells.

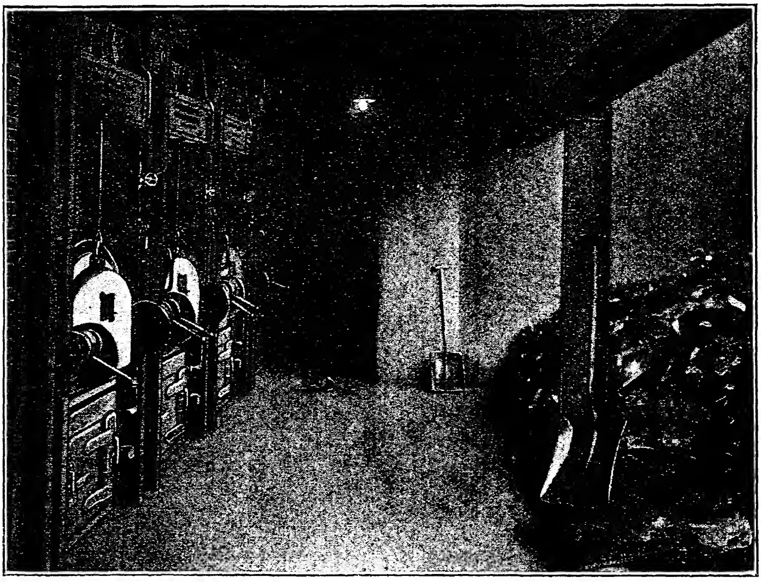

FIG. 38.—Blantyre Destructor, view of cells and refuse hopper.

required for forced draught and works purposes, the boiler is not set in brickwork but rests on cradles, the gases passing through the centre flue tube only. Forced draught is provided by steam-jet blowers, and the

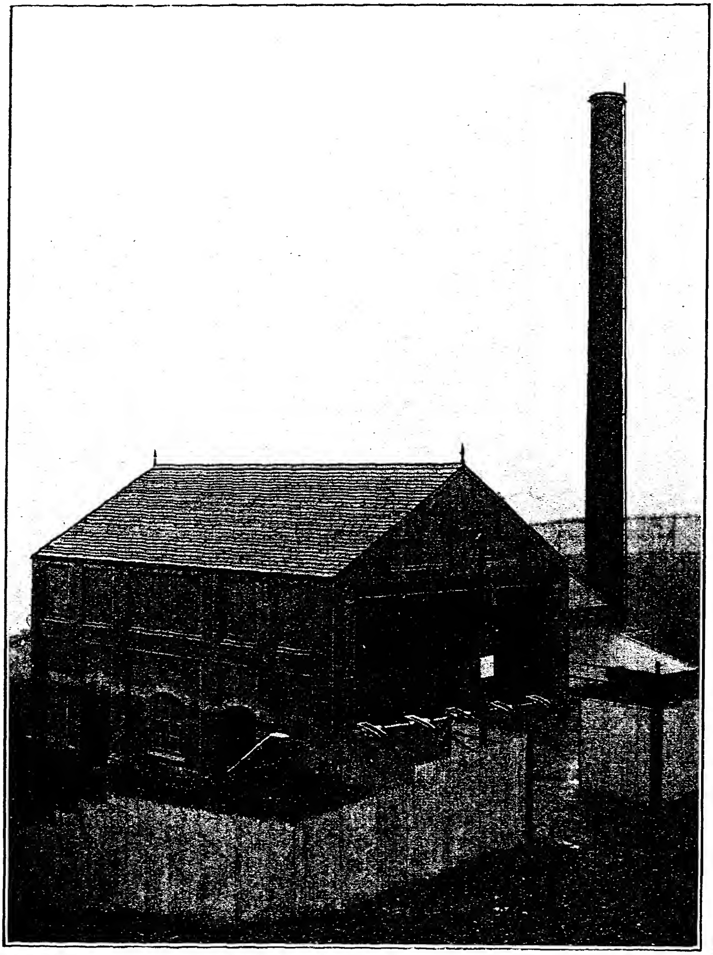

FIG. 39.—Blantyre (Lanark County Council) Destructor, view of building and chimney.

air supply is heated in a suction regenerator. The buildings are in corrugated iron, the chimney, which is of the Custodis type, is 70 ft. in height.

Under the present arrangement the Paignton Urban District Council deliver the refuse at the electricity works, and pay the Electric Light Company so much per ton for disposal.

BLANTYRE — LANARK COUNTY COUNCIL.

This installation, which may be taken as typical of the "Sterling" front-fed destructor, comprises a 3-grate destructor with a combustion chamber, a Lancashire boiler 28 ft. by 7 ft. 6 in. for a working pressure of 100 lbs. to the sq. in., steam-jet blower draught, and a regenerator. Fig. 38 is a view of the cells and refuse hopper. Fig. 39 illustrates the building, tipping platform, and steel chimney, which is 70 ft. in height, having an internal diameter of 3 ft. 6 inches.

The steam is utilised for forced draught, and for driving a small generating set for the lighting of the works.

CHAPTER VII.

THE DESTRUCTOR SITE.

DURING the past fifteen years about 200 refuse destructors have been erected in the United Kingdom: of this number, upwards of 150 have been erected on sites in close proximity to residential property, while a considerable number of destructors have been erected on centrally located and critical sites.

Nuisance of any kind is but rarely heard of, and it has been clearly shown that a destructor may be operated on the most central site with a complete immunity from offence.

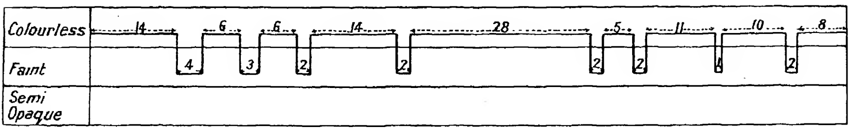

FIG. 40.—Diagram showing condition of the products of combustion as discharged from the chimney of the "Sterling" Front-Fed Destructor at Blantyre.

It is no exaggeration to say that the discharge from the modern destructor chimney is of a much less offensive nature than is the case with the average coal-fired boiler chimney.

Fig. 40 is a diagram prepared by the engineer to the public health department at Hamilton, as the result of observations of the destructor chimney at Blantyre, N.B.

From a ratepayer's point of view, the central site is of great importance, inasmuch as the cost of haulage is reduced to the minimum, in addition to which the scavenging is done quickly.

The importance of carefully considering the cost of cartage need not be emphasised: whether the refuse be 10 tons or 150 tons daily, when once the point of disposal is settled the charge becomes a perpetual one.

Further, and again from the point of view of the ratepayer, it is very desirable that if possible the steam should be fully utilised. If this can be done on a central site then so much the better. As a general rule

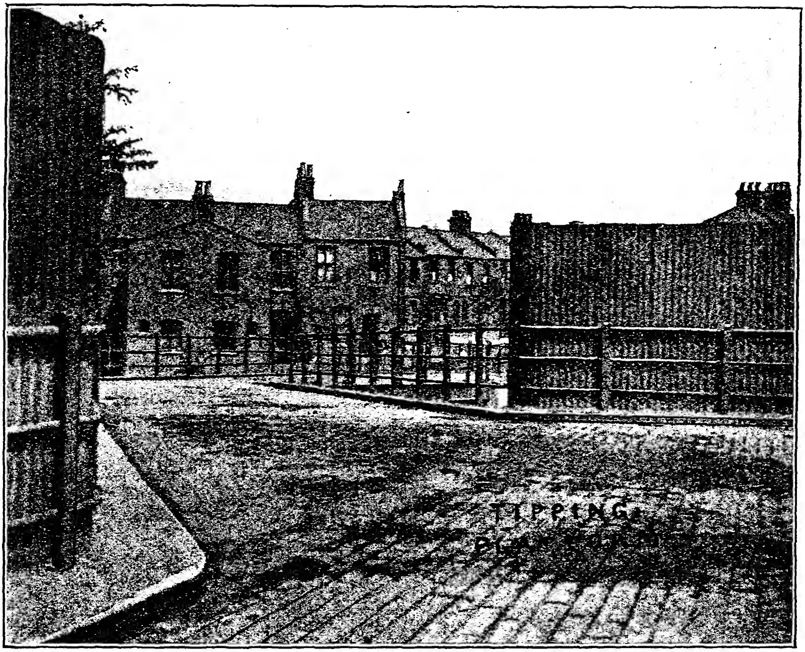

FIG. 41.—Walthamstow Urban District Council Destructor, showing close proximity of houses.

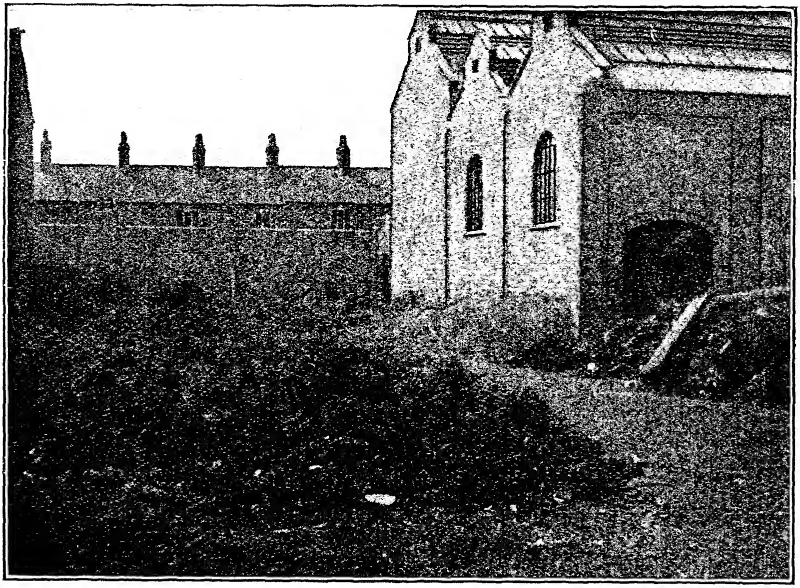

FIG. 42.—Kettering Destructor, view showing houses overlooking the destructor yard.

the electricity works is so located that a considerable saving in cartage cost can be effected as compared with cartage to the refuse tip.

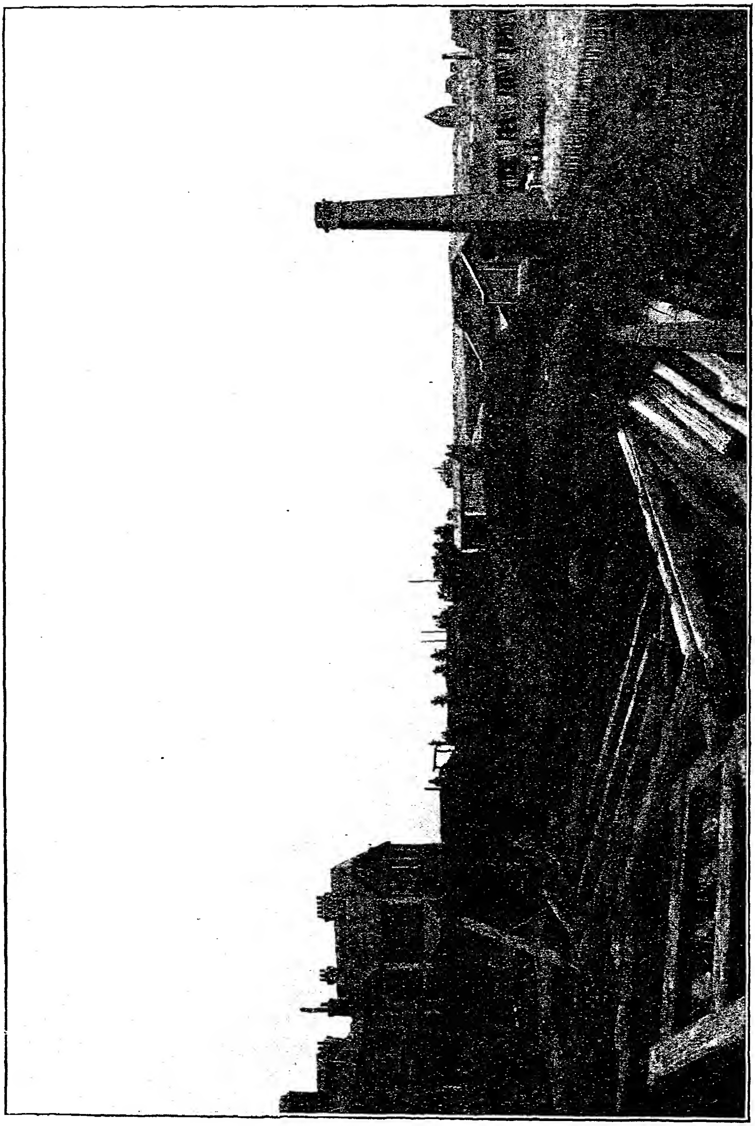

Fig. 43.—Weymouth Destructor, showing chimney, and villas overlooking the works

While both sewage works and, under certain circumstances, water works, provide a profitable outlet for the steam available from a destructor, frequently these works are so located that, from a cartage

point of view, the cost of collection and delivery is but little cheaper than when the refuse is tipped. On the other hand, there are both sewage and water works in considerable number which are so located that a reasonably low cartage cost could be secured in perpetuity if these sites were chosen for the erection of destructors.

The cost of cartage is so serious and the advantages of centrally located sites has been so clearly shown that the author has thought it desirable to illustrate some destructor sites and their surroundings:—

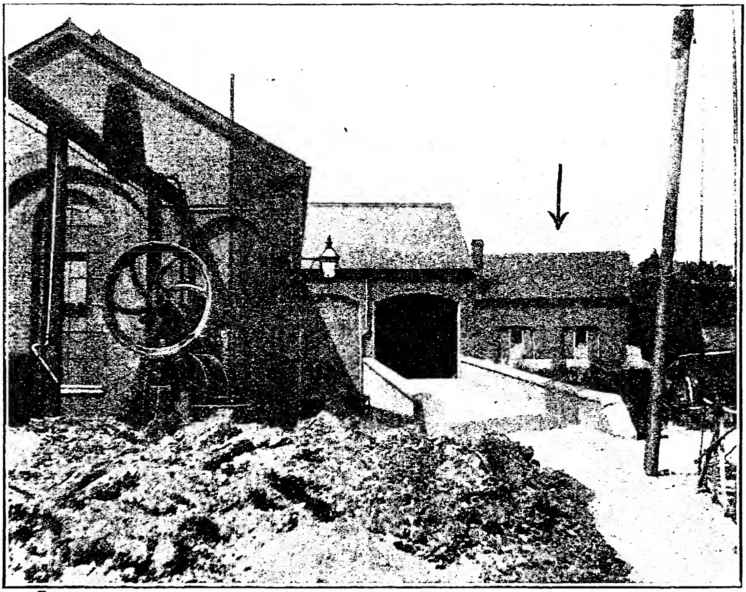

FIG. 44.—Sheerness Destructor (arrow indicates school, adjoining tipping platform).

Fig. 41 is a view taken from the tipping platform of the Walthamstow Urban District Council's destructor and sewage works.

Fig. 42 illustrates the end of the destructor building and the clinker yard at Kettering, where the destructor is combined with the electricity works. In the background and overlooking the works, houses will be observed.

In fig. 43 the combined destructor and sewage works of the Corporation of Weymouth are illustrated: these works are situated within five minutes' walk of the centre of the town.

The location of the destructor and water works of the Sheerness Urban District Council is seen clearly in fig. 44, a school, with open windows, overlooking the approach to the destructor tipping platform.

Figs. 45 and 46 serve to illustrate the critical location of the destructor at Wrexham, which is combined with the electricity works.

The destructor works at Moss Side belonging to the Corporation of Manchester are illustrated in fig. 47, and it is worthy of note that the houses overlooking the destructor works have been erected since the destructor has been in operation.

The author was intimately concerned with the erection of the

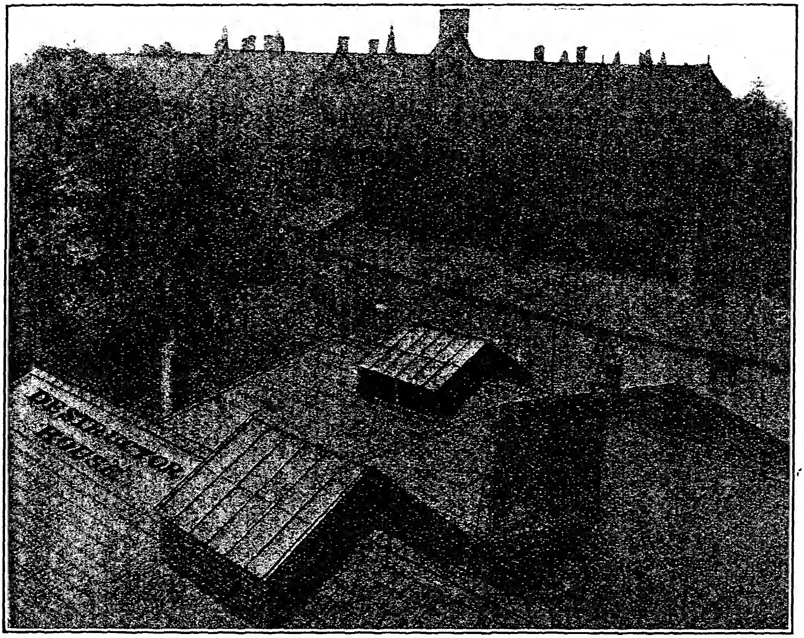

FIG. 45.—Wrexham Destructor buildings, showing critical location.

destructors at Walthamstow, Kettering, Weymouth, and Sheerness, and strongly advocated the sites chosen. These works have been in operation for from seven to nine years past, with a complete immunity from nuisance, while the saving in cartage cost alone has been very considerable.

At Kettering the saving in the cost of cartage is £250 per annum, and at Weymouth and Sheerness £234 and £300 per annum respectively, in addition to which in each case the steam is fully utilised.

Fig. 48 is a view of the destructor site at Prahran (Melbourne), the selection of which aroused much hostility. In a paper contributed

to the Australian Public Health Association, Mr W. Calder, the city engineer of Prahran, made the following observations: –

"In England opposition to the erection of refuse destructors was long sustained, but in later years this prejudice is dying out, and the more progressive communities have begun to consider the destructor as a necessary sanitary adjunct.

"In a country where little is known regarding refuse destructors, it

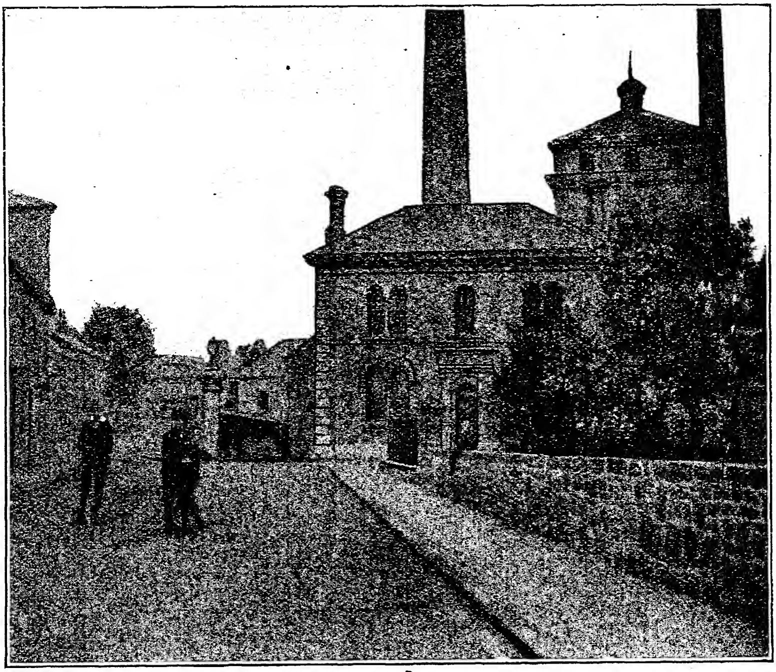

FIG. 46.—Wrexham Destructor, showing houses adjoining the works.

was scarcely to be expected that there would be no opposition to the Prahran installation.

"The garbage tip has long been a familiar feature in Melbourne and suburbs. The population had grown up with them until they had almost come to look upon them as old friends whose 'failings even leaned to virtue's side.' Many who would philosophically behold the accumulating pile of refuse at the tip undergoing the slow process of fermentation, object in the most forcible language to the operation of a destructor. Should its chimney emit a light vapour, it is described as belching forth volumes of nauseating smoke, and the particles of soot

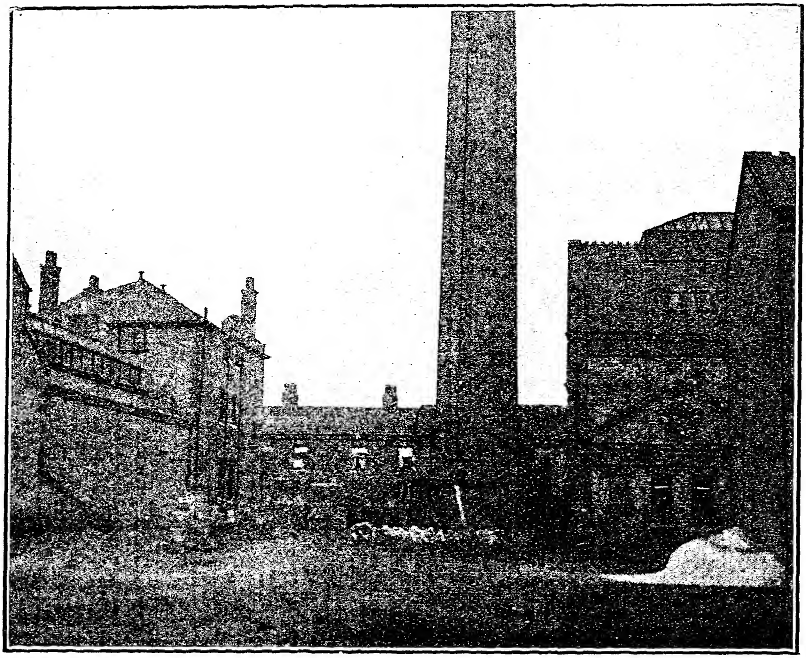

FIG. 47.—Moss Side (Manchester) Destructor yard, showing houses overlooking the works.

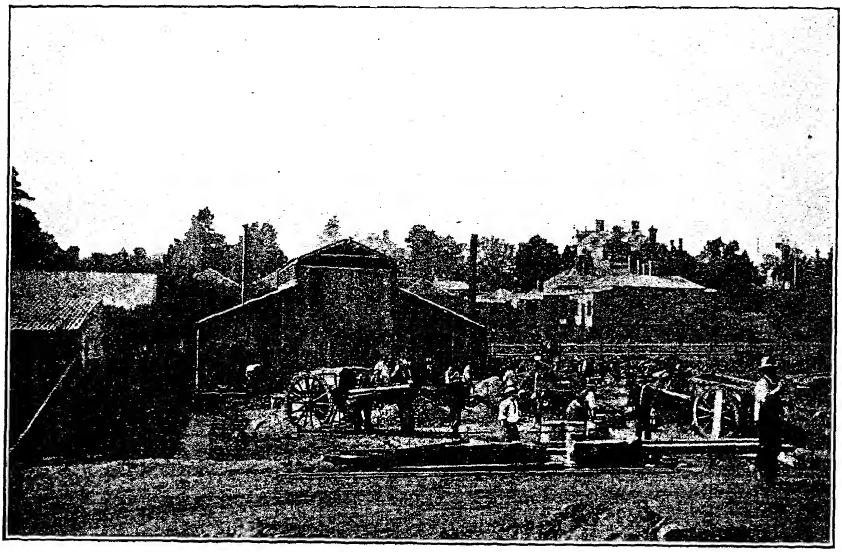

FIG. 48.—Prahran (Melbourne) Australia Destructor site.

and carbon given forth by passing trains, and from factories or domestic chimneys, are at once placed to the credit or discredit of the destructor, in whose flues not a particle of soot is to be found. The old insanitary high refuse carts passed the citizens' doors to the tip unheeded, but the neat, modern, low-bodied carts, introduced by the council, designed with tight-fitting metal covers, and set low on the axle, are vehemently objected to because their destination is the destructor instead of the tip. They are unsightly, insanitary, and noisy, though mounted on springs for the express purpose of reducing noise. The exhaust and waste steam issuing from the boilers, which are fed with Yan Yean water, is said to emit a horrible smell, because these boilers are heated with destructor furnaces.

"Needless to say, the great majority of the complaints have, on investigation, been found to be without foundation. One complaint was actually made regarding the smell before the furnaces were at work or any refuse had been delivered at the destructor. Others have been made regarding smells on Sundays, though under no circumstances has there been any refuse remaining over from Saturday evening. But in some the imagination is vivid, and prejudice dies hard with the majority of us."

Mr Calder's statement is no exaggeration, and it is but typical of what actually happens in this country. Prejudice here may be dying, but it expires very slowly; those who have been concerned with the installation of refuse destructors in England will be well aware that nearly every site chosen for a refuse destructor is objected to.

Mr Calder anticipated opposition at Prahran because, as he says, 15,000 miles away from England, little is known regarding refuse destructors. The truth is that here in England where over three hundred destructors are in daily operation, an ignorance has to be combated such as is probably without parallel in any other country.

The author recalls that when the Kettering Urban District Council decided to erect the destructor on a central site adjoining the electricity works some eight years since, he was invited by the council to deliver a series of three lantern lectures to some hundreds of the ratepayers to show what a destructor really was, and to endeavour to prove that destructors were actually in existence elsewhere, and in many instances on central sites.

While this educational work, of which the author has done a great deal, had the effect of breaking down much ignorant opposition prior to the Local Government Board inquiry, a large sum of money had been subscribed for the briefing of counsel to represent the opposition, and

the Kettering council were opposed at the Local Government Board inquiry, but all to no purpose. The Local Government Board sanctioned the application of the Kettering council and the destructor was erected: not a single complaint of nuisance of any kind has ever been received.

The author could refer to many other similar cases; probably there will be many more in the years to come. The attitude of many ratepayers towards the provision of a refuse destructor is incapable of explanation. It is impossible to please the man who does not object to the presence of a refuse tip near to his house, but wishes a refuse destructor to be erected some miles out of the town; it is useless to argue with this class of individual; he must be fought in the interests of the ratepayers generally.

CHAPTER VIII.

DESTRUCTOR SPECIFICATIONS.

It is very desirable that specifications for refuse destructors and accessories should be clearly drawn, and that the engineer responsible for the preparation of the specification should indicate clearly what is required.

In the desire to be fair to the various makers, there is at present a tendency to issue outline specifications only, with the result that the tenders and schemes submitted vary to such an extent that it is impossible to find any common basis for comparison.

Under such circumstances it is frequently found that the destructors offered vary in type from mechanical-feed to shovel-feed. Some makers offer Water-Tube boilers, others Lancashire, Cornish, or even multitubular types. The boilers vary greatly in heating surface, and accordingly in price. Some makers include regenerators, others do not; in some schemes fan draught is included, in other schemes steam-jet blower draught. The buildings vary in character, size, suitability, and cost. The chimney may be 150 ft. in height or only 80 ft., while in many other important details the schemes will materially differ.

Even if the schemes are critically compared in detail, which unfortunately does not always happen, the practice of inviting tenders on an open specification is unfair, inasmuch as most makers are in a position to tender to specific requirements, and much prefer to do so. When it is proposed to spend the minimum amount on a destructor plant, it is, to say the least of it, utterly absurd to issue such a specification as may lead a reputable firm to offer a scheme of such a nature as cannot possibly be accepted, whatever its merits may be, because of the price.

Faced with a number of schemes varying widely in design and cost, the course sometimes adopted is not to accept any tender, but to settle upon a type, and then to invite fresh tenders. Much waste of time and money might be avoided if the type were chosen and specified originally.

When tenders are invited for a specific type of destructor the specification should be as complete and definite as possible, so that tenders may be fairly compared with the minimum of trouble.

Unless this course is adopted the engineer will experience some difficulty in making a fair comparison between the various schemes submitted, a task which demands considerable care, however complete the specifications may be.

In comparing tenders and schemes it is of the utmost importance to look closely into all the details of the specification and the drawings, not only in fairness to those who have tendered, but also to make certain that the tender accepted shall be for a scheme which embodies all the features which are necessary for securing the maximum working efficiency, reliability, low maintenance cost, and facilities for easy operation, under comfortable working conditions.

Maximum Working Efficiency.—To ensure the maximum working efficiency it is, for instance, of vital importance to specify a destructor of the "continuous-grate" type in preference to the "cellular" or isolated-cell type. It is unnecessary to discuss the relative advantages of the two systems here, as this matter is fully dealt with in another chapter. It will suffice to say that the question is no longer a debatable one.

Reliability.—Absolute reliability is essential, and there is much in every destructor scheme which will either ensure reliability or the reverse.

No mechanically-fed plant is, or can be, as reliable, *at all times and under all conditions*, as a simple top- or shovel-fed destructor. It cannot be too frequently urged that simplicity conduces to reliability.

Next to the destructor, the boiler calls for special consideration, and as a general rule it is advisable to have the specification for the boiler and its accessories prepared by a Boiler Insurance Company, and to arrange with them for complete inspection and testing at the maker's works and on the site. If this course is adopted, and it is inexpensive, much trouble is saved, and those tendering are brought into line.

The boiler feed pump should be of first-class make, of ample capacity, and capable of meeting variable demands over a wide range. Those tendering should be required to state in their specification the name of the proposed maker. Some cheap pumps give much trouble and cannot be relied upon.

The author has endeavoured to bring together in the form of a draft specification those important features, based upon the best modern practice, for ensuring first-class material, the most durable construction, the minimum cost for repairs and maintenance, efficient operation, and satisfactory working conditions.

SPECIFICATION.

The destructor shall be of the   fed type, capable of burning to an innocuous and vitreous clinker   tons of refuse per day of   hours.

Lining of Cells.—The interior of the cells or furnaces shall be lined with firebrick 9 in. thick from two courses below grate level. The first five courses above the grates shall be headers to minimise the damage caused by firing tools.

Wall Thickness.—The front walls of the furnaces shall be 14 in. thick of firebrick throughout, the end and back walls shall be 23 in. thick, including 9 in. of firebrick. All bridge walls shall be 18 in. thick in firebrick above the grate level.

Facing Bricks, etc.—The facing bricks for the furnaces (and boiler setting) to be the best pressed red bricks: samples are to be submitted for approval.

For all work between the external walls and the lining good wire-cut or common red bricks are to be used, samples of which are to be submitted for approval.

Firebricks.—The firebricks are to be heavy, hard, close grained, and well burnt, and of the best Stourbridge or equal make: samples are to be submitted for approval.

The firebricks shall be laid with the thinnest possible joints in best fireclay cement.

For all firebrick arches[1] special radiated or purpose made bricks shall be used.

Framing.—The furnace and ashpit fronts shall be securely bolted to a rolled steel framing, consisting of bulb tees and channels to act as buckstaves, the tops of all buckstaves being tied by rods $1\frac{1}{4}$ in. diameter, the bottoms resting upon cast-iron shoes firmly bedded in concrete.

Staying.—The whole structure shall be stayed with compound buckstaves of 6 in. × 3 in. H iron, provided with distance pieces, and firmly bolted together. The furnace shall be tied by means of stay rods $1\frac{1}{4}$ in. diameter, having screwed ends $1\frac{1}{2}$ in. diameter. To permit of free expansion the rods should preferably be enclosed in tubes embedded in the concrete filling.

Labour.—(An optional but very desirable clause.)—It is desirable that this class of work should be done by experienced men, and those

[1] The best practice in arch construction is to spring the arches from heavy cast-iron skew-backs, bolted to the buckstaves; above the 9 in. firebrick arch, with an air space of 3 in. between, a 9 in. red brick arch should be provided. For durability this method of construction is superior to any other, as the arches stand well. and the side walls can be cut away and repaired whenever necessary without in any way interfering with the arch.

tendering will not be permitted to sublet the furnace brickwork or flues in connection therewith, either locally or otherwise.

Protection of Lining.—For minimising the adherence of clinker to the firebrick walls, solid sloping deadplates in heavy cast iron, at least 9 in. wide, shall be provided, or, alternatively, the walls shall be faced with cast iron air-cooled protection plates, extending at least 9 in. above grate level.

Combustion Chamber.—A combustion chamber of ample size shall be provided, and shall be so arranged that the gases from the grates shall be thoroughly mixed, and the maximum of dust intercepted. The combustion chamber walls shall be lined with the best Stourbridge or equal firebricks, 9 in. thick, the floor[1] shall be formed of similar firebricks, 4½ in. thick, laid on edge. The arch construction shall be similar in every respect to the arch construction for the furnace. The combustion chamber shall be provided with one large cleaning door for access to the chamber; this door shall be preferably of the vertical lifting type, arranged to slide between guides in a massive frame. The door shall be hung on wire ropes connected to balance weights, and shall be machine-faced and lined with firebrick.

Main Flue.[2]—The main flue shall be of ample cross-sectional area, and lined with firebrick 4½ in. thick.

Bye-pass Flue.—The bye-pass flue shall be of ample cross-sectional area and lined with firebrick 9 in. thick. A suitable cold-air inlet door and frame shall be provided, the door being capable of regulation for admitting air for the dilution of the gases.

Furnace Fittings.—Each furnace shall be provided with the necessary doors, door frames, furnace and ashpit fronts, deadplates, firebars, bearers, door balance weights, pulleys, etc.

Furnace Doors.[3]—All charging and clinkering doors shall be in heavy cast iron, preferably of the guillotine type, and shall be lined with firebrick, properly balanced, and arranged to make joint on machined faces.

Access and Cleaning Doors.—With the exception of the access doors to the combustion chamber and furnace ashpits, all access doors shall be of the lift-off type, of ample size, and sufficient in number and in suitable positions to facilitate the work of inspection and cleaning. The doors and frames shall have machined faces to make tight joints.

[1] The combustion chamber floor should be at least 12 in. below the level of the clinkering floor.

[2] If it is proposed, at some future time, to extend the destructor, the main flue should be large enough to provide for such extension.

[3] The type of charging doors in top-fed destructors may be left to the maker, but gas-tight doors should be insisted upon. Water seals are not at all desirable under such conditions as obtain in the destructor building.

Cast Iron.—All cast iron used, with the exception of that used for balance weights, shall be tough, close-grained, and of good quality, free from blowholes or other defects.

Wrought Iron.—All wrought iron shall be of the "Best Best" or other approved brand.

Boiler.—The boiler shall be of the type, and shall conform strictly to the following specification. Those tendering are required to include in their tender the sum of £ to cover the cost of inspecting and testing the boiler. [Here insert complete specification of Boiler Insurance Company.]

Boiler Setting.[1]—The outside walls shall be 18 in. thick, the firebrick lining throughout shall be 4½ in. in thickness, the best Stourbridge firebricks or equal shall be used for this purpose, and a sample shall be submitted for approval.

Feed Pump.—The boiler feed pump shall be of or other approved make, and shall be capable of delivering gallons per hour against a boiler pressure of pounds to the square inch.

Injector.—The injector shall be of Gresham & Craven's, White's, or other approved make, capable of delivering gallons per hour against a boiler pressure of pounds to the square inch.

Feed-Water Supply Tank.—A feed-water tank for the boiler supply, having a capacity of gallons, with the necessary supports, shall be supplied and fixed in a suitable position. The tank shall be covered.

Water Softener.[2]—A water softener of the Lassen & Hjort or equal make shall be supplied and fixed in a suitable position. The softener shall have a capacity of gallons per hour, and shall be capable of reducing the hardness of the water from ° to °.

Steam and Water Pipework.—Those tendering are required to include in their tender for supplying and fixing such steam and water piping as is required within the destructor building only, with the exception of the exhaust steam from the feed pump or fan engine which is to be led outside the building. All steam piping above 1 in. in diameter should be flanged. All steam fittings shall be in gun-metal, heavy pattern.

Covering of Boiler and Steam Piping.—The boiler and such steam piping as come within the scope of this contract shall be covered in a suitable manner with the best non-conducting composition.

[1] With a water-tube boiler, if it is proposed to use the same boiler for supplementary coal-firing, the firebrick lining should be 9 in. thick where the temperature will exceed 1000° Fahr.

[2] The feed water should be, preferably, analysed.

Accessories.[1]—The following accessories shall be provided:—

.... complete sets of firing tools.

.... clinker barrows.

Forced Draught.—If steam-jet blowers are proposed for this purpose they must be arranged to work noiselessly. Ordinary open blowers will not be deemed satisfactory.

Each blower shall be provided with a separate valve and cock, so arranged as to be easily removable for repair.

Air Heating.—The air supply for combustion shall be continuously heated, preferably by means of a regenerator or recuperator arranged beyond the boiler. No method of air heating will be deemed satisfactory which does not utilise the waste heat for this purpose. Those tendering are required to state the average temperature of the hot air in the air-conduit, which they must be prepared to guarantee (see Guarantee, 5). Further, the number of regenerator tubes should be stated, as also their length and diameter, and the method of attachment or connection to the plates.

Ventilation of the Building.—Means for continuous and positive ventilation of the building shall be provided, preferably by means of the forced-draught apparatus, which should be so arranged as to take the entire air supply for combustion from within the building.

Maintenance.—The maintenance period shall be [2] months from the time of lighting the slow-drying fires, during which period the contractor shall execute all repairs which may become necessary owing to faulty workmanship or material, fair wear and tear excepted.

Terms of Payment.—The contractor shall be entitled to receive during the progress of the work 80% (eighty per cent.) of the contract price, and upon completion of the contract and after the due performance of the guarantees a further 10% (ten per cent.). The remaining balance of 10% (ten per cent.) shall be paid to the contractor [2] months after the completion of the work and the fulfilment of the guarantees.

Guarantees.—The nature and scope of the guarantees will vary according to the character of the plant and the requirements therefrom, but the following guarantees will suffice for ordinary purposes:—

(1) The destructor of grates or cells shall consume continuously under normal working conditions tons of such refuse as is usually collected in per day of hours.

[1] This list may, of course, be extended to cover any other tools or spare parts which may be considered desirable.

[2] This may be six, nine, or twelve months; six months is a reasonable period.

(2) There shall be an entire immunity from nuisance in the form of smoke, fumes, or dust, both from the chimney and the building.

(3)[1] The evaporation per pound of refuse destroyed during the winter months shall be   , and during the summer months   , in both cases calculated as from and at 212° Fahr. The guaranteed evaporation shall be *net,—i.e.* after allowing for the use of steam required for forced draught, feed pump, etc.

(4)[2] The average combustion chamber temperature shall be not less than   ° Fahr., and the minimum temperature shall not be lower than   ° Fahr.

(5)[3] The average temperature of the hot-air supply for combustion shall be not less than   ° Fahr.: this temperature shall be ascertained in the hot-air conduit.

(6) The clinker shall be vitreous and free from organic and combustible matter. In winter the percentage of clinker and ash shall not exceed   per cent., and in summer   per cent.

(7) Under normal working conditions the labour required for the burning of   tons of refuse, as set forth in Guarantee (1), and the removal of the clinker outside of the building, shall be   men per shift of   hours.

Penalty for Non-fulfilment of Guarantees.—In the event of failure in the performance of any one of the afore-mentioned guarantees a sum shall be deducted from the contract sum equivalent to   [4] per cent. thereof. At the same time, if any one or more of the other guarantees given is exceeded or improved upon, this shall be taken into consideration.

The Destructor Building.—It is very desirable that destructor buildings should be well provided with light and air, and they should be reasonably spacious, to provide the most comfortable working conditions possible. The provision of messroom accommodation, lavatories, and bath, as well as lockers for clothes, are points which should receive careful consideration.

The Chimney.—While a high chimney is not necessary, to meet sentimental objections it is frequently found desirable to provide a

[1] In connection with a plant for steam generation this is a very desirable course to adopt, in which case a twenty-four hours' test would be made at each season.

If separate guarantees for winter and summer are not asked for, the guarantee given must obviously be speculative, as at the time it is given it is impossible to determine when the test may be carried out.

Steam Pressure.—In all cases where the steam is to be fully utilised for operating pumping or electric generating plant, those tendering should be required to guarantee the margin of variation in the boiler steam pressure.

[2] 1800° Fahr. average and 1400° Fahr. minimum are reasonable figures.

[3] 250° Fahr. is suggested.

[4] This figure is usually 1 per cent.

chimney 120 ft. in height or even more. This is a point which will depend upon the location of the plant and sentiment.

Dust Retention.—With a well-designed modern plant, having a properly proportioned combustion chamber and a dust pit under the regenerator, no separate dust catcher is necessary. With the aforesaid provisions the dust is retained at convenient points for easy removal; and unless an excessive air pressure is used, the dust does not travel to any serious extent beyond these points.

Tests.—The usual short test of eight or twelve hours and sometimes less is of but little service; under such conditions, when the plant is being operated by skilled and expensive labour, phenomenal results are obtained, but such results afford no real guide as to the results obtainable under normal working conditions over an extended period.

The real test of a plant is the actual results shown under normal conditions over a long period, when it is invariably found that the average results fall considerably short of the test results.

When a destructor is erected with a view to effecting a definite saving in coal consumption, for instance in conjunction with a sewage pumping plant, the author would recommend that the test should cover three months' normal working. In any case, *no test should cover a shorter period than twenty-four hours*, and no test should be carried through by the skilled firemen of the contractor, but by the staff of the local authority, after training by the contractor's fireman, under the supervision of the contractor's engineer.

The author has known cases where during a short test the skilled fireman sent by the contractor has handled from 30 to 40 cwts. of refuse per hour, whereas, on the following day, and under ordinary working conditions, two men have failed to do equivalent work.

CHAPTER IX.

DESTRUCTOR DESIGN AND OPERATION.

THE AIR SUPPLY FOR COMBUSTION.

ONE of the most difficult problems presented in destructor design is the satisfactory provision and arrangement of the air supply. For many years there was a disposition to treat this problem lightly, and without due regard to the many important points which are involved.

In the design and arrangement of the air supply considerable experience in combustion engineering is demanded, and the more closely the cardinal principles governing combustion are adhered to, the more efficient will be the results obtained.

Having determined the volume of air which must be provided, the next important question is that of areas. Since the introduction of the regenerator for air heating this problem has become more difficult and demands very careful consideration.

The provision of ample area for the passage of the air supply is of the utmost importance, and much depends thereon. The author recalls two recent cases which have come under his observation which will serve to show that at times insufficient attention is devoted to this important point. In both cases fan draught is used without regenerators. In one case in London the air pressure at the fan outlet averages 3 in. water gauge, while in the ashpits the average pressure is 1 in. only.

At a Continental installation the author found an average pressure of 5 in. at the fan outlet and an average of 1 in. only in the ashpits. In this instance the thickness of the fire varied from 3 ft. to 4 ft., the refuse being of an exceedingly poor character, requiring an ashpit pressure of from 4 in. to 5 in. at least. Owing to the provision of very small air mains of considerable length and very badly arranged, the loss was serious.

There are cases on record where the air supply has been insufficient, but such cases are happily rare (in the majority of cases precisely the

opposite conditions obtain); not only does an insufficiency in the air supply involve inefficient working, but also the liberation of a considerable volume of CO (carbon monoxide), which is a poisonous gas.

Under satisfactory conditions, with a sufficient volume of air, the CO is burned to CO_2 (carbon dioxide). In every well-designed plant this is the object; how far it is accomplished depends not entirely upon the design of the plant and the arrangement of the air supply, but to a considerable extent upon the operation of the plant.

Having this in mind, it is well worth while to install at destructor works the necessary apparatus for ascertaining the composition of the gases of combustion. By proper attention to the regulation of the air supply and the condition of the fires it is not at all difficult to show a percentage of CO_2 in the gases, varying from 12 per cent. to 18 per cent., according to the working conditions.

At the present time there are at least two CO_2 recorders on the market which are simple, easily understood, do not require skilled attention, and are very accurate, while the price is very moderate—from £30 to £40. It is not necessary to use apparatus of this kind continuously; if put into use occasionally it will be found very valuable, as affording a check upon the operation of the plant, and will conduce to efficiency.

For the provision of the air supply either a fan or steam-jet blowers may be used; within recent years fan draught has been more extensively adopted. In the case of destructors combined with electricity undertakings, and in other cases where the power is to be fully utilised, there is a disposition to adopt fan draught, because the steam required to drive a fan is less than is utilised with steam-jet blowers—assuming the volume of air delivered by each to be the same.

While the steam consumption is a point of much importance in a combined destructor and electricity works, and although at times the choice hinges entirely on this factor, there are other factors which claim consideration.

Steam-Jet Blowers.—Curiously enough, both steam-jet blowers and fans were introduced in destructor practice about the same time. Mr W. Horsfall was the first to use the former, while the latter was first used in 1885 by Mr John Young, then Superintendent of Cleansing to the Glasgow Corporation.

In actual steam consumption it is generally admitted that the fan has the advantage. Steam-jet blowers use from 12 per cent. to 14 per cent. of the total water evaporated, and these figures refer to blowers of the most efficient design. Some blowers of crude design use considerably

more than the percentages named and are exceedingly inefficient. In the design of steam-jet blowers the main problem presented is precisely the same as in the design and arrangement of the fan and its motive power, *i.e.* to deliver a given volume of air with the smallest consumption of steam.

In simplicity, first cost, reliability, and maintenance cost, the steam-jet blower has the advantage. Fans are frequently duplicated—a wise course to adopt; steam-jet blowers are never duplicated, this course being unnecessary because of their absolute reliability.

It has been urged that the clinker produced where steam-jet blowers are used is inferior and of a more open and friable character than that produced in destructors provided with fan draught; this is entirely contrary to the author's experience.

Some three years since, in a town about twenty miles from London, the sewage works were being remodelled, and a very considerable quantity of clinker was required for the construction of filter beds. In spite of the fact that a modern destructor provided with fan draught was in operation in the town in question, the borough surveyor decided that the clinker was unsuitable, and he purchased some thousands of tons of clinker from a neighbouring town where a destructor provided with steam-jet blower draught was in use. The cost of the clinker was 2s. 8d. per ton in trucks in the siding at these works, and the total cost d/d was about 4s. per ton.

Referring to fans and steam-jet blowers, Mr D. M'Coll, the well-known Cleansing Superintendent to the Corporation of Glasgow, expressed the following opinion:—

"Both methods were in operation in connection with the Glasgow Corporation Cleansing Department, of which he had charge, and his experience was that the steam-jet blower was the better, the results being more satisfactory. He admitted that the jet used more steam, but after all it was but a small proportion of the total generated, and there was this advantage, that the breakdown of a jet only affected the grate to which it was attached, whereas if the fan got out of order the whole installation was affected. . . . He considered the clinker produced in the steam-jet blower furnace superior to that from the fan blast furnace, and he had never had the slightest difficulty in finding purchasers for it."

For many years past the Glasgow Corporation have derived a considerable revenue from the sale of clinker; in all probability, far more in this direction has been done in Glasgow than in any other city. Mr M'Coll's opinion is therefore a very valuable one.

One point which should not be overlooked in connection with steam-jet blowers is that they are arranged to work at the point where they are actually required, *i.e.* in the ashpits. Under these conditions, if ample area is allowed through the regenerator and in the air conduit to the steam-jet blowers, there is no appreciable loss in efficiency.

Steam-jet blowers should always be enclosed and arranged to work with a freedom from noise. At the present time there is a tendency to use open-type blowers, more particularly for stand-by purposes. All open steam-jet blowers are exceedingly noisy in operation, and are very objectionable. Further, the employment of blowers of this type involves the use of cold air, which is another unsatisfactory feature.

Fans.—Within recent years fan draught has been extensively adopted. With steam-driven direct-coupled fans the steam consumption varies from 5 per cent. to 10 per cent. of the total evaporation, according to the efficiency of the engine. Generally speaking, small engines are not at all economical in steam consumption. Not only does the steam consumption vary considerably, but the efficiency of fans varies materially, and the rivalry among fan-makers is very keen.

It is now generally conceded that it is advantageous to impart moisture to the air supply from a fan, and in some cases the fan engine exhaust is thus utilised. It is now claimed that the moisture in the air merely facilitates the removal of the clinker. Some years ago, in connection with a patent covering the combination of an exhaust steam nozzle with a centrifugal fan, it was claimed that "it affects a considerable advantage in combustion."

The reason why this claim is no longer made is obvious: those interested in fan draught have persistently asserted, in connection with steam-jet blower draught, that the moisture present in the air is of no advantage in the combustion process; under these circumstances it is obviously futile to claim an advantage for fan draught with moist air which they decline to admit with the steam-jet blower delivering moist air.

Whether the fan is driven by means of a direct-coupled engine or belt-driven, it requires considerably more attention than steam-jet blower draught, and is not so reliable.

The following extract from *The Contract Journal*, dated June 22, 1910, refers to a combined destructor and electricity works. No good purpose can be served by disclosing the name of the town; the author is merely desirous of showing that the fan is not so reliable as the steam-jet blower.

"Originally forced draught was provided by a fan, but owing to

the continual breakdown of the vertical high-speed engine this system was abandoned in favour of steam-jet blower draught, which was installed last year (1909). The change has been a great success *in many ways*."

In connection with several installations during recent years a separate fan has been provided for each cell; while this tends to improve the efficiency and conduces to reliability, it obviously adds materially to the capital expenditure.

Having in mind that so much depends upon the air supply, it is of great importance to duplicate the same. In some installations, not only is the fan draught duplicated, but in addition to this, steam-jet blowers are provided.

Many electrical engineers prefer, and insist upon the installation of, motor-driven fans, which undoubtedly possess many advantages. The adoption of electrically-driven accessories may, however, be carried too far; the author is connected with a generating station in which considerable economy has been effected by the general abandonment of motor-driven accessories for steam-driven accessories; the number of "station units" used in some works reaches a very high figure.

The consumption of energy for driving fans varies considerably, and may be as low as 2·5 per cent. or as high as 8·5 per cent.; it is, however, but fair to point out that the latter figure, which was the average for one year at the Greenock combined destructor and electricity works, may be accounted for by the abnormal air pressure used.

The Advantages of Heated Air.—The value of hot air is now generally recognised, both for the efficient burning of very inferior refuse containing an abnormal percentage of moisture, as also for refuse of a more carbonaceous character.

With the use of heated air the excess air supply may be reduced, conforming more closely to the theoretical requirements. A cubic foot of air at 32° Fahr. is increased in volume $\frac{1}{273}$ for each additional degree of temperature Centigrade, or about $\frac{1}{491}$ for each additional degree Fahrenheit. Thus by heating the air to 273° Centigrade (or 491° Fahr.) it will be doubled in volume, and one cubic foot will then weigh only half as much as before.

With refuse of an inferior character, heavily charged with moisture, the use of hot air is of the utmost importance; in fact, the proper application of hot air makes all the difference between success and failure with very low grade refuse, which frequently cannot be burned without the use of coal when cold air is employed.

The capacity of air for absorbing moisture increases very rapidly

with the temperature. In his *Practical Treatise on Heat,* Thomas Box states that dry hot air at 300° Fahr. has two hundred times the capacity to absorb moisture possessed by air at 60° Fahr.

The rapid absorption of moisture secures earlier ignition, while the recovery of temperature is greatly accelerated. Further, the cell temperature is higher and is more easily maintained. As a matter of fact, in many instances the temperature has been too high, and the present tendency is to restrict the temperature within such limits as will tend to prevent the rapid fusion of intercepted dust in the combustion chamber.

Even when the refuse is unusually high in calorific value with but an average percentage of moisture, if the power is to be utilised, the use of hot air will materially increase the working efficiency due to the intensified combustion.

Mr W. H. Booth, whose work in combustion engineering is well known, thus puts the case for hot air:—

"The gain in economy and efficiency by raising the combustion temperature within the furnaces by the use of heated air is great, *especially if heat otherwise wasted is supplied to heat the incoming air.*"

While Mr Booth was referring to steam boiler furnaces and the burning of coal, his opinion equally well applies to the burning of refuse. While the actual gain in economy must obviously be greater in the burning of any kind of coal, yet the peculiar advantages of the regenerative system in burning refuse are greater because of the presence of moisture.

Systems of Air-heating, Side Air Boxes.—The first system of air heating introduced was the side air boxes of Messrs Horsfall, for which it was claimed that not only was the air-supply for combustion considerably heated, but the side walls were preserved. The author has always favoured a system which utilises waste heat for air heating rather than the use of heat which is required in the cell, but to avoid any suggestion of prejudice it is as well to quote the opinion of another.[1] Mr J. A. Robertson, Chief Engineer of the Greenock combined destructor and electricity works, expressed the following opinion:—

"The author has found in practice that the comparatively small heating surface of the boxes and the rate at which the air must travel through them does not permit of a higher temperature than 180° Fahr. being obtained at the outlet, while a further disadvantage is that the amount of heat imparted to the air depends upon the temperature of the

[1] See "Refuse Destructors and Electricity Works," by Mr J. A. Robertson, paper read before the Glasgow Section of the Institution of Electrical Engineers, Feb. 8, 1909.

furnace, the draught is lowest immediately after charging, *i.e.* just at the time when high temperature is most needed to dry the refuse and to commence combustion."

The two points referred to by Mr Robertson are the crucial points. (1) The area of the heating surface and the rate of the flow of the air, and (2) the fact that the air temperature is necessarily at its lowest when it should be at its highest.

The efficiency of any system of air heating is in the main determined by two factors, (1) the temperature of the gases for transmission, and (2) the area or surface provided for the transmission of heat; further, any system of air heating cannot be regarded as a really satisfactory one unless it provides for the use of waste heat.

The Regenerator.—A properly designed regenerator or recuperator fulfils these requirements; it is placed beyond the boiler, it has ample heating surface, and whether it is of the suction or pressure type is invariably efficient. The whole volume of gases from one unit passes through the regenerator, and a common hot air conduit with branches to each ashpit is provided; it follows, therefore, that hot air is available just when it is needed most, *i.e.* after clinkering and recharging. In other words, the temperature of the air supplied to any one grate is not determined by the conditions obtaining on the one grate in question. In this important respect the regenerative system of air heating essentially differs from the side air box system.

In American practice there is a tendency to place the regenerator in the boiler setting of a water-tube boiler, it being arranged in the final pass of the gases at the back of the boiler.

While there is a small gain in actual ground space occupied, on the whole this course cannot be recommended. In temperature the gain is trifling, and in the burning of garbage or very wet refuse it is found that the tube deposit which cakes hard is very serious. Further, the position of the regenerator under such conditions renders cleaning difficult; and, owing to the incrustation and restriction of the area, more frequent cleaning is necessary, in addition to which this work takes much longer to do.

Utilisation of Heat from Clinker.—In the United States many experiments have been made with a view to the utilisation of the heat in the clinker for the heating of the air supply, but no data is available, and the author has reasons for thinking that the results obtained have been disappointing.

When considering the possibilities of thus heating air, one is bound to take into account the fact that the volume of air to be heated is very

considerable as compared with the surface or cubic capacity of the clinker available. Again, the cooling process is exceedingly rapid.

In one experiment on a somewhat small scale, air at a temperature of 84° Fahr. was heated to 423° Fahr. in passing through hot clinker, but after five minutes the air temperature dropped to 270° Fahr. The very rapid cooling of the clinker, with the simultaneous decrease in air temperature, would seem to suggest that but little can be hoped for in this direction.

High-Pressure Air Supply. — In connection with some modern mechanically charged destructors working with very thick fires, the air pressure required varies from 6 in. to 12 in. of water gauge. Taking the German practice of 12 in. as compared with 2 in.—which is common practice in England—the power required to deliver an equal volume of air will be six times greater. This is a point which is frequently overlooked, in addition to which is the dust trouble, and this, despite all that may be said to the contrary, is very serious.

The extraordinary measures adopted by German engineers for the interception and removal of dust afford ample proof were it needed.

The German destructor chimney is a notorious offender in the discharge of dust, although unusual means are adopted for the interception of the same. A further point is that the upkeep and maintenance cost with high capacity cells must be, and is, considerably greater than is the case with cells of moderate capacity.

The power required to drive a fan increases as the cube of the velocity. Obviously, therefore, the speed of a fan should not exceed that proper to the desired draught. In other words, it is exceedingly uneconomical to use a small fan driven at a high speed in order to obtain a large volume of air. The best practice is to employ a fan of ample size to give the volume of air required at the minimum pressure.

Ventilation of Building.—Closely involved with the question of air supply is the ventilation of the destructor house. One of the most interesting developments in destructor practice during the past few years has been the attention devoted to forced ventilation, which has had the effect of materially improving the working conditions.

There is an impression in some quarters that the question of ventilation has only received consideration since fan draught has been more extensively employed; and further, that a system of positive ventilation involves the use of fan draught.

As a matter of fact, the author was the first to introduce this method of continuous ventilation, some nine years since, at the Watford destructor and sewage pumping station, and in this instance steam-jet

blower draught was, and is still, employed. The air for combustion is drawn from the top of the building through the regenerator inlet, and it soon became evident that the atmosphere of the building and the working conditions were vastly improved.

The importance and value of such a provision cannot be exaggerated; not only is the atmosphere changed, but the continuous suction has the effect of securing the rapid removal and deposit of dust carried in suspension. Fumes and dust, two of the most objectionable features of the average destructor building, are no longer a source of offence.

Under ordinary conditions, without provision for positive ventilation upon the lines indicated, louvres have been provided in the apex of the roof, with the result that gases and dust escape continually; in fact the discharge at this point is often greater and more serious than the discharge from the chimney.

For ventilation on the lines herein indicated the roof must be closed, air ducts or conduits being arranged from the top of the buildings, the clinkering floor, and from any other point which may be desirable, communicating directly with the fan inlet where the regenerator is of the pressure type, and where the regenerator is of the suction type, to the regenerator inlet. Under these conditions it will be found, with open doors in the building, that there is a gentle inflow of air, in contrast to a belching forth of fumes and dust, an all too familiar feature under ordinary conditions.

THE STEAM BOILER.

The Position of the Boiler.—The position of the boiler in relation to the destructor cells is a factor of considerable importance. The provision of a combustion chamber of ample size between the cells and the boiler should be insisted upon as an absolute necessity, having in mind that the *primary* purpose of the destructor is to destroy refuse with an immunity from nuisance.

Further, the provision of a combustion chamber is of importance to secure the immediate interception and settlement of a considerable proportion of the dust, at a point where it can be quickly removed, and to ensure the minimum deposit of dust on the heating surface of the boiler, and in its setting and flues.

When the combustion chamber is omitted and a boiler set between two cells, the gases passing from the cells come into direct contact with the boiler, which involves immediate cooling. The conditions thus presented are precisely opposite to those which obtain when a combustion chamber is provided, and the author would submit that the

conditions are unfavourable from a sanitary point of view, and that the first deposit of dust is confined to the heating surfaces of the boiler and its setting.

In the generation of steam the results will be fairly good, due to the direct action of flame upon the heating surface. When a combustion chamber is provided, very little, if any, flame reaches the boiler, but a complete diffusion of the gases is secured at a high temperature, and this is the point of vital importance.

Type of Boiler.—Boilers of four types are being used in connection with destructors—water-tube, Lancashire, Cornish, and multitubular or fire-tube.

Cornish Boiler.—In reviewing the relative advantages of each type a brief reference to the Cornish boiler will suffice. It has been adopted in a number of the smaller combined destructor and sewage works, and has invariably given very satisfactory results. In other works, where it is not possible to fully utilise the power, the Cornish type has fully met all requirements at a low capital expenditure, and with a freedom from trouble.

Multitubular Boiler.—The multitubular, or fire-tube, boiler, which was the first type of boiler to be used in connection with refuse destructors, is most unsatisfactory, owing to the very rapid choking of the tubes with dust. In modern destructor practice it is but rarely, if ever, adopted, and cannot be recommended.

Water-Tube Boiler.—During the past few years the water-tube boiler has been very extensively adopted; it possesses peculiar advantages for the utilisation of waste gases, in addition to which its setting provides useful space for the deposit of dust.

As a quick steaming boiler the water-tube type is favoured for use with destructors combined with electricity works. While responding quickly to a rising temperature, owing to the limited steam and water space, a drop or fluctuation in temperature has an immediate effect upon the steam pressure.

For a varying load the author has frequently recommended the use of a steam and water drum, 12 in. greater in diameter than that of the standard drum for a boiler of given heating surface, and this has invariably proved beneficial.

The water-tube boiler occupies considerably less floor space than the Lancashire boiler, and this is often found to be very advantageous. Further, it lends itself to alternative coal firing, which is at times exceedingly useful if there should be a shortage of refuse. Various attempts have been made to increase the duty from a boiler by firing

the same both with destructor gases and coal, but the combination is not a satisfactory one; it is impossible to obtain a reasonable efficiency from coal when passing a large volume of destructor gases over the fire.

Lancashire Boiler.—A considerable number of boilers of this type are in use with destructors, both in combined destructor and electricity works, and also combined destructor and sewage works.

The outstanding advantages of the Lancashire boiler are (1) its simplicity, (2) its large steam and water capacity. In destructor practice both of these points are important. The large steam and water capacity, which are, in effect, thermal storage, are often found of great advantage, and, as a general rule, the steam pressure maintained with a boiler of this type is much more steady and regular than with the water-tube type.

The Lancashire boiler is not a quick steaming boiler, and does not respond as rapidly to a rise in the temperature of the gases as does the water-tube boiler: it is mainly for this reason that the Lancashire boiler is not now so extensively adopted in combined destructor and electricity as was the case a few years since.

Another objection to this type of boiler is the deposit of dust in the flue tubes, and this applies equally to the Cornish type. The author is of opinion that this trouble can be greatly minimised if those responsible for the design of the destructor provide a door or doors in the wall of the combustion chamber directly opposite to the firebrick-lined connecting tubes. If this were done it is possible to prevent the incrustation of the firebricks, which quickly reduces the exit area from the combustion chamber, causing back draught and a stoppage for cleaning.

Much of the trouble with dust deposited in the flue tubes might be avoided if the dust in the combustion chamber were raked out on alternate days, or even daily. If the combustion chamber door is lifted about one foot at a convenient time, the dust can be raked out in five minutes.

In the majority of cases this is not done, with the result that the level of the dust in the combustion chamber rises, less dust is intercepted, and accordingly more is carried forward into the flue tubes and boiler setting. Further, the upper layer of dust in the combustion chamber is carried by the current of gases into the flue tubes, while the mass of dust in the combustion chamber gradually fuses.

Under proper conditions, if the suggestions here discussed are adopted and the plant is well designed, it is possible to operate a destructor with a Lancashire boiler for three months without a stoppage.

As a matter of fact, at present, the average installation cannot be operated for more than from four to six weeks; this is not due to the type of boiler, but solely to those causes here referred to.

The Lancashire boiler does not lend itself to separate coal firing when set for destructor firing; this is a disadvantage as compared with the water-tube boiler, which, as already observed, is well adapted for this purpose.

In all cases where the steam is to be fully utilised for the operation of generating plant or pumping plant, it is advisable to arrange for a margin of at least 20 lbs. between the boiler pressure and the pressure of steam required at the engines; for example, if steam is required at the engines at a pressure of 160 lbs., the boiler working pressure should not be less than 180 lbs. to the sq. in.

This margin of pressure and the provision of the necessary reducing valve will be found very serviceable in securing a steady steam pressure at the engine, allowing, as it does, for variation in the refuse and an occasional lack of attention.

The provision of a continuous steam-pressure recorder is strongly recommended, as tending to keep a very useful check upon the operation of the plant, and in enabling responsibility to be definitely fixed.

Feed Water.—With water-tube boilers it is very necessary to devote due attention to the feed water. Unless a supply of soft water is available the feed water should be analysed and its hardness determined with a view to the provision of a water softener if necessary.

In many districts the provision of a water softener would avoid much trouble and labour with Lancashire and Cornish boilers. All feed water should be suitably treated *before* being supplied to the boiler; the function of the boiler is to generate steam, and not to soften or purify feed water.

THE CHIMNEY, BYE-PASS FLUES, AND DUST RETENTION.

Chimney.—With a well-designed modern destructor a high chimney is unnecessary. Many of the most successful destructors in the United Kingdom are provided with chimneys varying from 45 to 100 ft. in height.

In order to ensure satisfactory working, the flues leading to the chimney should be of ample cross-sectional area, and this applies also to the chimney itself, the object being to decrease the velocity of the gases as much as possible, and so prevent dust being carried in suspension. To

this end it is also desirable that the temperature of the gases at the chimney base should be reduced to 250° or 300° Fahr.

Bye-pass Flue.—Unless it is absolutely necessary, a bye-pass flue is not desirable; it introduces a complication which might often be avoided with advantage; it involves the use of dampers which are exposed to very high temperatures, and which are troublesome and expensive to maintain.

Assuming, however, that the provision of a bye-pass flue is imperative, its cross-sectional area must be amply large in order to reduce the velocity as much as possible; further, it is desirable to provide means for introducing air to dilute and cool the gases.

When a bye-pass flue is provided it is advisable to line the chimney throughout in firebrick. The system of lining adopted by the Alphons Custodis Chimney Construction Company is a good one, the lining being arranged in sections carried on corbels, which much facilitates repairs should these become necessary.

Dust Retention.—The interception of dust is referred to at some length in other chapters, and it will suffice to say that much depends upon the design of the destructor flues and chimney, as also upon the operation of the plant.

In every case where a suitable combustion chamber is provided and kept clean the bulk of the dust is intercepted and removed at this point. When a suitable dust pit is provided underneath the regenerator the dust which has been carried beyond the boiler is deposited here and very little reaches the main flue. When a bye-pass flue is arranged from the combustion chamber to the main flue at a point near the chimney, if the bye-pass flue is continually used, not only must it be of large area, but it is advisable to provide a simple form of dust catcher of large capacity, with easy access thereto.

The bye-pass flue is the most troublesome factor in connection with dust, and if this can be dispensed with no difficulty whatever is presented with a well-designed plant operated with reasonable care and attention.

OPERATION COSTS, LABOUR, AND MAINTENANCE.

Labour.—The labour cost per ton of refuse destroyed is generally understood to include (1) all wages paid for the actual handling of the refuse when delivered at the works; (2) the removal of the clinker from the destructor building; and (3) the cost of supervision at the works. With regard to the latter charge, this varies considerably. In connection with combined destructor and sewage works, for instance, it is usual to

TABLE XI.—COMPARATIVE LABOUR COST PER TON OF REFUSE DESTROYED.

97 Installations.

Top-fed.	Power used for	Pence per ton.	Top-fed.	Power used for	Pence per ton.
1. Acton	Works	10·70	21. Fulham	Electrical purposes	17·00
2. Accrington	Electrical purposes	15·80	22. Glasgow	Sewage pumping and works	9·00
3. Aston Manor	Works	12·00	23. Gloucester	Electrical purposes	20·00
4. Ashton-under-Lyne	Electrical purposes	16·50	24. Grantham	Works	16·00
5. Barrow-in-Furness	Do.	11·50	25. Kensington	Do.	9·00
6. Bath	Works	14·75	26. Leeds	Do.	12·00
7. Bournemouth	...	9·80	27. Llandudno	Electrical purposes	15·25
8. Belfast	Works	9·00	28. Northampton	Do.	17·30
9. Birmingham	Do.	10·00	29. Plymouth	Works	12·13
10. Bermondsey	Electrical purposes	13·90	30. Saltley	Sewage pumping	9·50
11. Birkenhead	Works	20·00	31. St Helens	Electrical purposes	13·70
12. Bootle	Do.	9·00	32. St Pancras	Works	13·75
13. Bury	Sewage pumping	8·75	33. Southport	Gas works	18·00
14. Burton-on-Trent	Works	16·50	34. Stepney	Electrical purposes	16·75
15. Bristol	Do.	10·00	35. Stretford	Works	15·50
16. Bradford	Electrical purposes and works	11·75	36 Torquay	Do.	18·50
			37. Warrington	Electrical purposes	14·00
17. Canterbury	Electrical purposes	27·00	38. West Bridgford	Sewage pumping	12·00
18. Colne	Do.	14·00	39. Wimbledon	...	21·00
19. Derby	Works	10·80	40. Wolverhampton	Electrical purposes	11·00
20. Eastbourne	Sewage pumping	22·00			

Mechanically-fed.	Power used for	Pence per ton.	Mechanically-fed.	Power used for	Pence per ton.
41. Blackpool	Works	13·00	47. Nottingham	Electrical purposes	11·00
42. Brentford	Sewage pumping	21·00	48. Poplar	Do.	10·69
43. Brighton	Works	11·00	49. Shoreditch	Do.	22·10
44. Cambridge	Sewage pumping	12·00	50. Wandsworth	Works	12·00
45. Greenock	Electrical purposes	13·25	51. York	Electrical purposes	18·00
46. Leeds	Works	7·40			

Back-fed.	Power used for	Pence per ton.	Back-fed.	Power used for	Pence per ton.
52. Batley	Electrical purposes	13·54	63. Moss-side	Works	10·50
53. Bury St Edmunds	Do.	10 00	64. Oldham	Do.	9·75
54. Cheltenham	Do.	12·00	65. Padiham	Do.	15·75
55. Clydebank	Works	16·00	66. Pontypridd	Electrical purposes	15·00
56. Dunoon	Do.	14·00	67. Radcliffe	Sewage pumping	10·50
57. Falmouth	Electrical purposes	9·00	68. Ramsgate	Works	11·00
58. Folkestone	Works	14·85	69. Rotherham	Electrical purposes	12·43
59. Gosport	Sewage pumping	13·00	70. Stockton	Do.	12·00
60. Gorton	Do.	11·50	71. Swansea	Do.	14·80
61. Lowestoft	...	13·33	72. West Bromwich	Do.	15·00
62. Luton	Sewage pumping	10·00	73. Wood Green	Works	16·00

Front-fed.	Power used for	Pence per ton.	Front-fed.	Power used for	Pence per ton.
74. Aldershot	Sewage pumping	9·00	86. Kettering	Electrical purposes	11·00
75. Ayr	Electrical purposes	16·00	87. Heywood	Works	14·00
76. Burnley	Do.	13·00	88. Lytham	Sewage pumping	8·50
77. Burslem	Do.	18·00	89. Mexborough	Electrical purposes	13·00
78. Cambuslang	Do.	9·50	90. Nelson	Do.	16·00
79. Cleckheaton	Do.	12·00	91. Lancaster	Do.	14·00
80. Darwen	Do.	14·00	92. Preston	Do.	13·00
81. Eccles	Sewage pumping	10·64	93. Sheerness	Water pumping	12·00
82. Elland	Electrical purposes	12·00	94. Todmorden	Electrical purposes	7·20
83. Epsom	Sewage pumping	11·00	95. Walthamstow	Sewage pumping	12·00
84. Exmouth	Adjoining brick works	11·50	96. Watford	Do.	14·00
			97. Wrexham	Electrical purposes	14·00
85. Hyde	Sewage pumping	16·00			

divide the cost of supervision between the destructor and the sewage pumping station, while in other works the total cost of supervision is usually charged to the destructor.

It is very difficult to obtain accurate figures of labour cost, although it would seem to be perfectly simple to treat the destructor as a separate undertaking, and keep a clear record of all income and expenditure; unfortunately in many cases this is not done, and it is for this reason also that it is so difficult to ascertain the precise cost of maintenance.

While every effort has been put forth to ensure the accuracy of the labour cost figures in the accompanying Table XI., it is necessary to observe that in many of the smaller installations, where the cost per ton destroyed is high, this is entirely due to the fact that the staff employed could deal with a greater quantity of refuse, and as the quantity increases, so will the cost per ton destroyed decrease.

Taking the installation in Table XI., the average cost per ton of refuse destroyed with each type is as follows:—

Top-fed, . .	40	installations	= 14·12	pence	per	ton.
Mechanically-fed,	11	„	= 13·72	„	„	„
Back-fed, . .	22	„	= 12·72	„	„	„
Front-fed, .	24	„	= 12·54	„	„	„

The average labour cost in connection with the 97 installations of four types is 13·37 pence per ton of refuse destroyed.

The advantages of mechanical and top charging from a labour-saving point of view have been continually urged, and for the former, in particular, extravagant claims have been made. It is now generally recognised that little, if any, advantage is secured in the labour cost, and this is borne out by such data as is available.

Maintenance.—Such figures as are available all tend to show that the cost of maintenance is lowest with destructors of the continuous-grate shovel-fed type; further, the most satisfactory records are in connection with front-fed destructors. The maintenance cost records in connection with 44 installations will be found in Table XII.

The actual cost of maintenance, while being an important factor, is in some cases regarded as of little consequence when compared with the disorganisation and inconvenience caused by stoppages, which, in the case of a destructor supplying steam, are very serious. In order to ensure a low maintenance cost and absolute reliability, simplicity in design is essential: to this may be attributed the satisfactory record of the continuous grate and shovel feeding.

TABLE XII.—REPAIRS AND MAINTENANCE COSTS.

44 Installations.

	Type.	Power used for	Cost per Annum.
Acton	Top-fed	Works	First 2 years, £12 10 0
Aldershot	Front-fed	Sewage pumping	,, 7 ,, 0 11 6
Ayr	,,	Electrical purposes	,, 2½ ,, 2 16 0
Batley *	Back-fed	,, ,,	First year, { 40 14 1=1908. 56 4 6=1909.
Belfast	Top-fed	Works	100 0 0
Bridport	Back-fed	,,	First 3 years, 6 15 2
Burslem	Front-fed	Electrical purposes	1½d. per ton, including tools, barrow, etc.
Cambuslang	,,	,, ,,	,, 3 ,, Nil
Chesterfield	Back-fed	Sewage pumping	,, 5 ,, £5 17 10
Chiswick	,,	,, ,,	15 0 0
Cleckheaton	Front-fed	Electrical purposes	,, 4 ,, 3 7 0 (since, £12 per annum).
Clydebank	Back-fed	Works	7 0 0 year ending May 15, 1909.
Dunoon	,,	,,	4 16 10
Eccles	Front-fed	Sewage pumping	,, 3 ,, 4 5 10
Epsom	,,	,, ,,	,, 4 ,, 1 5 0
Gorton	Back-fed	,, ,,	27 0 0
Gosport	,,	,, ,,	,, 4 ,, 10 0 0
Great Grimsby	,,	Works	,, 3 ,, 25 0 0
Grays	Front-fed	Electrical purposes	,, 5 ,, 4 0 0
Hyde	,,	Sewage pumping	,, 2½ ,, Nil
Ipswich	,,	Electrical purposes	£25 0 0
Kings Norton	Back-fed	Works	,, 3 ,, 38 15 6
Llandudno	Top-fed	Electrical purposes	25 0 0
Lowestoft	Back-fed	Works	,, 6¼ ,, 10 0 0
Lytham	Front-fed	Sewage pumping	,, 4 ,, 3 15 0
Leigh	Back-fed	Works	40 0 0
Moss Side	,,	,,	25 0 0
Mexborough	Front-fed	Electrical pumping	,, 4 ,, Nil
Oldham	Back-fed	Works	£60 0 0
,, (Rhodes Bank)	,,	,,	100 0 0
Padiham	,,	,,	,, 5 ,, 10 0 0
Pembroke (Dublin)	,,	,,	20 8 2
Port-Glasgow	Front-fed	,,	,, 2¼ ,, 35 0 0
Preston	,,	Electrical purposes	,, 2 ,, 17 16 0
Salisbury	Back-fed	Sewage pumping	,, 3½ ,, 10 0 0
Sudbury	Front-fed	...	,, 3 ,, 5 3 5
Stoke-on-Trent	,,	Electrical purposes	,, 2 ,, 10 0 0
Sheerness	,,	Water pumping	,, 4 ,, 10 0 0
St Helens	Top-fed	Electrical purposes	5d. to 9d. per ton.
Taunton	Back-fed	Sewage pumping	,, 3½ ,, 35 0 0
Watford	Front-fed	,, ,,	,, 3 ,, 8 0 0
Weymouth	,,	,, ,,	,, 3 ,, 3 3 4
Withington	,,	,, ,,	,, 2 ,, 8 19 4
Wrexham	,,	Electrical purposes	,, 4 ,, 21 0 0

* Including structural and boiler repairs.

Mr D. M'Coll, Cleansing Superintendent for the Corporation of Glasgow, comparing top- and front-fed destructors—both types of which he has in use—expressed the following opinion:—

"Being just over the grate, the top-feed openings were exposed to the full radiated heat, and required frequent renewal, which meant practically rebuilding the whole arch, and this ran up the cost of upkeep to a very high figure. In a report which he had submitted recently, he recommended the substitution of a front feed, having been satisfied that by this method the work could be done in a cleanly manner, the refuse by the one operation spread evenly, and the cost of repairs materially reduced. There was no doubt that the dumping of large quantities of refuse into a furnace retarded combustion and lowered the temperature for the time being, and this was avoided by the front-feeding process."

In order to show to what extent the guaranteed maintenance cost varies according to the type of destructors, the following figures are of interest. In this instance the destructor was required to dispose of 130 tons of refuse daily, and those tendering were requested to guarantee the annual cost of maintenance for a few years.

A. Top-fed . .	£20 to £25 per annum.
B. Top-fed . .	£200 per annum after first two years.
C. Top-fed . .	½d. to 1d. per ton for three years.
D. Mechanically-fed	½d. per ton for furnaces, flues, and dampers, or for whole plant 4 per cent. of contract sum per annum.
E. Back-fed . .	£75 per annum after first two years.
F. Top-fed . .	£20 to £30 per annum for furnaces.

While these figures are of interest, strictly speaking, they are not fairly comparable, owing to the considerable variation in the scope of the guarantees. Another point is the cost of each plant, which may in some cases have been increased with a view to guaranteeing low maintenance cost. With a well-designed plant, into which the best of materials and workmanship has been put, it is obvious that, fair wear and tear excepted, much will depend upon the efficiency of the supervision.

It is necessary to direct attention to this because it is well known that the supervision in some works is very lax indeed, simple and inexpensive repairs being neglected, until it eventually becomes necessary to shut down the plant and spend a considerable sum, much of which may be attributed to neglect.

For thorough cleaning and boiler inspection, it is necessary periodically to shut down for at least one week: during this time the whole plant and its accessories should be carefully inspected; any repairs, even of a trivial character, should then be done. Under these conditions smooth working is ensured, and a stoppage is only likely as the result of an accident or some failure which could not be foreseen.

CLINKERING.

The most arduous and disagreeable work in the operation of a destructor is the removal of the clinker from the furnace, and then from the building.

Under the most favourable circumstances, the clinkering of 25 square feet of grate will occupy at least ten minutes. With modern high temperature destructors, the breaking up of the mass on the grate involves a preliminary loss of at least five minutes, and with heavy charges much longer; but when broken, the material may be quickly removed.

There is no doubt that in most destructor works the operation of removing the clinker from the building is rendered far more disagreeable than is necessary, owing to prejudice upon the part of the men.

The usual method is to use a barrow with a single wheel, and this is *pushed*, with the result that the hot gases and dust are carried over the man behind. Almost every effort to introduce a barrow with two wheels, which can easily be *pulled*, has failed. Even in works where the clinker is removed from the building in skips carried on a mono rail, the men will persist in pushing the skip instead of pulling it.

The mono rail or clinker railway was introduced some years ago, with a view to facilitating the removal of the clinker from the building, but here again much prejudice has been shown, and in more than one works the mono rail has been abandoned in favour of barrows.

A mono-rail installation at Stoke-on-Trent destructor works is illustrated in fig. 49.

One of the difficulties experienced with this method of clinker removal is due to the limited space available for tipping the material, which must be frequently removed or the use of the mono rail must cease until the ground is cleared.

A tipping car, running on sunk rails, is illustrated in fig. 50. This method has been adopted in a few works, but it is open to the same objection as the mono rail and skip.

In Canada and the United States, in connection with some few destructor installations, a shoot is provided in the clinkering floor immediately in front of each grate, the shoot communicating directly either with trucks placed on the floor beneath, or a clinker cooling chamber. With this arrangement the clinker has only to be broken and pulled out of the furnace, and to some extent the labour is thus reduced.

The satisfactory removal of the clinker from the grate automatically or by mechanical means is not an easy matter. Many years ago tipping

grates were tried with clinker trucks in the ashpits, but were quickly abandoned in favour of fixed grates. Fire-bars having a reciprocating movement have been tried; with low temperature destructors they were found to be unsatisfactory, with high temperature destructors they are impossible.

Any method of automatic or mechanical clinkering is unsatisfactory which does not provide for the rapid ignition of the fresh charge. It is

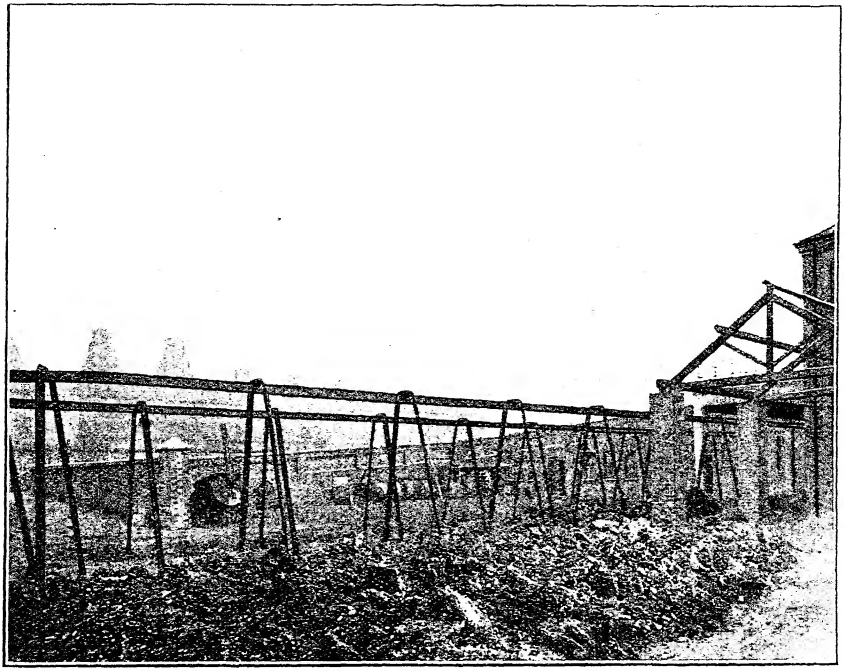

FIG. 49.—Clinker Mono Railway, Stoke-on-Trent Destructor Works.

not a difficult matter to merely pull out or push out the clinker bodily; the troublesome feature is that after this operation nothing remains with which to ignite the fresh charge. Further, the handling of the clinker after removal from the cell involves much labour.

The ignition difficulty is troublesome to overcome because, unless the clinker is thoroughly well burned down and consolidated, it cannot be removed in the mass. If it is removed in the mass, then the fresh charge cannot be rapidly ignited, as nothing is left on the grate to start the fire.

In connection with the clinkering device, tested at New Brighton, New York, which is described and illustrated in Chapter XII., see fig. 79,

it is said that the clinker, after removal and deposit in the chamber under the grate, furnishes sufficient heat to ignite the new charge.

This being so, then there is a grave risk of overheating the grate above, and this is to some extent confirmed by Mr J. T. Fetherston, who expressed the opinion that the dumping of an imperfectly consumed charge might give trouble, and that absolutely trustworthy labour is of vital importance.

The patent trough and clinkering apparatus, as installed at Hertford

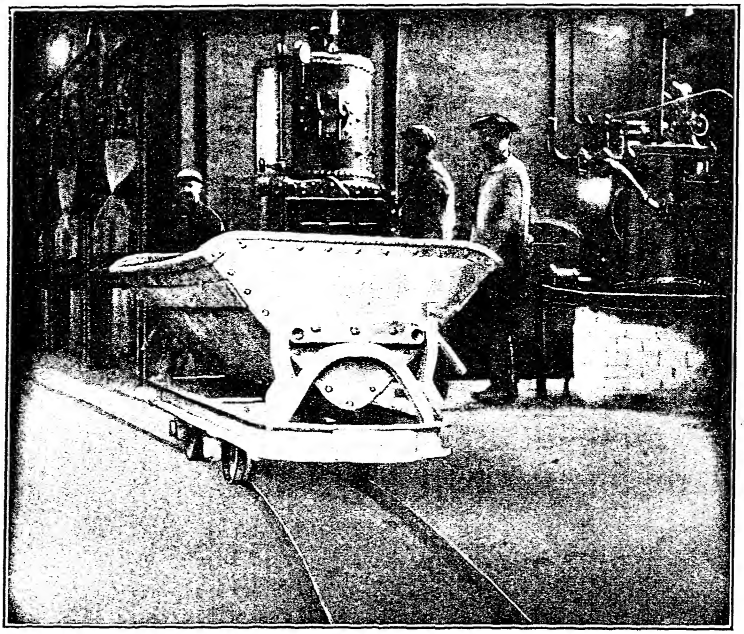

FIG. 50.—Side Tipping Clinker Truck, Bromley Destructor.

in connection with a Heenan front-fed destructor, has inclined sides, constructed in cast-iron plates, which are perforated for the admission of the air supply, which is delivered through the lower portion of the sides.

The back of the trough is in solid cast iron, while in the base of the trough at the centre is a longitudinal groove or recess in which the clinker draw bar rests. This draw bar is in the form of a T iron, the upper face of which is perforated. The groove in which the draw bar rests is sufficiently wide to permit of air under pressure from the ashpit being delivered on either side of the draw bar, the air supply thus being confined to the centre of the base of the trough and the lower portion of its sides.

At its rear end the draw bar is provided with a rectangular plate projecting upwards. When a charge of refuse is burnt out and the door at the front—which is the whole width of the furnace—is lifted, the draw bar being pulled forward, the mass of clinker is removed, preferably directly on to a special form of trolley or truck. Usually the draw bar is operated by means of a winch; for the operation of the draw bars in a number of grates in one unit, a winch arranged to travel in front of the furnaces is employed.

An alternative arrangement to that in use at Hertford is to provide for forcing the clinker forward from the rear of the trough by means of a ram or pusher.

The average weight of refuse destroyed daily at Hertford is from 7 to 8 tons; the weight of clinker will therefore be from 35 to 45 cwt. daily.

The actual everyday working results in mechanical clinkering have yet to be demonstrated: whether those difficulties herein referred to can be successfully overcome time will show.

The English draw-bar clinker-removal device does not possess the disadvantage of being exposed to the mass of hot clinker immediately under the grate, inasmuch as the clinker is removed bodily from the furnace instead of being dumped below the grate.

At this time it is impossible to say to what extent labour will be displaced or the working conditions improved, nor is it possible to determine to what extent the working efficiency is affected.

It is very desirable that the removal of clinker should be made as easy and expeditious as possible, and any apparatus which will do this, while at the same time providing for the rapid ignition of the new charge, will meet a long-felt want. At the same time it is very important that when the mass of clinker is removed from the furnace, means shall be provided for its easy handling and removal from the building, or the advantage of easy removal from the grate may be neutralised by subsequent delay and labour in getting the mass away from the cell and outside the building.

CHAPTER X.

THE UTILISATION OF RESIDUALS.

THE utilisation of the principal residual, waste heat, for the generation of steam, is fully discussed in its various aspects in other chapters. The residuals other than waste heat will to some extent be determined by the size and organisation of the destructor works department, and they may comprise clinker, ashes, and flue dust only, or, in addition to these, tins, scrap iron, paper, and fish offal, each of which is in many works dealt with separately, and more or less profitably.

Even in the smallest works the tins are usually roughly sorted from the refuse and disposed of; scrap iron, which frequently includes bedsteads, is invariably removed and generally sold. Paper—with the exception of some of the larger cities which provide for a separate collection to some extent—is burned with the refuse. Fish offal is also burned as a general rule, but in some few cases it is converted into manure at the destructor works, or similarly disposed of at a local manure works.

The treatment and utilisation of tins, paper, and fish offal will be discussed later. The principal residual, and that which demands the most serious consideration, is the clinker, because of its relative proportion to the original.

In Great Britain the percentage of clinker varies with the season from 25 per cent. to 30 per cent., although there are cases on record where the lowest percentage has been 22 per cent. and the highest 36 per cent.

With destructors of the earlier types the clinker is frequently of a very unsatisfactory nature, and too soft to possess any commercial value, while in many instances it is not by any means free from organic and combustible matter.

In connection with some modern destructors improperly operated, and in some few cases of unsatisfactory design, the clinker is but little better than was the case some twenty years since.

These three classes of destructors are to some extent responsible for what has been termed "the clinker problem." Clinker has been put on the market which has failed to satisfy, with the result that many who have not been concerned with the cause have condemned the use of clinker for a variety of purposes.

In order to produce a good clinker, dense, vitreous, and free from organic and combustible matter, certain conditions must obtain; the material must be exposed to a well-sustained high temperature for a sufficient period. The length of time will depend, among other factors, upon the nature of the refuse, the thickness of the fire, the air supply, and the temperature.

It may be argued that these are not the only factors, and that the time for clinkering a fire must be determined by the steam requirements. If this factor is admitted, then it must necessarily follow that the cremation process is a secondary consideration, and that it is subordinate to the generation of steam.

Having in mind that the primary purpose of the destructor is to thoroughly burn the refuse, the generation of steam must necessarily be a secondary consideration. The author does not agree with those who assert that a good clinker cannot be produced if due consideration is given to the generation of steam.

To remove an imperfectly burned material in the form of clinker is of no benefit from the point of view of steam generation, because (1) there is a definite loss in fuel and heat units; (2) the too frequent cleaning of the fires increases the labour; (3) the periodic reduction in temperature involves a fluctuating steam pressure; and (4) the varying temperature increases the maintenance cost.

Taking the other extreme, there is no advantage in retaining the clinker in the cell too long, because when the material is well burned and active combustion has ceased the temperature obviously falls; the longer the clinker remains, the greater the loss due to an inactive grate.

Those conditions, which are imperative for the production of a good clinker, are precisely the same conditions which ensure the highest efficiency in the generation of steam. To argue that this is not so is to disregard the fact that by proceeding upon the same lines when burning coal would involve a serious waste, a fact which is too obvious to necessitate any further discussion.

Given a good vitreous clinker, what is to be done with it, and what is its value? This will depend to a large extent upon local conditions; among the various purposes for which clinker has been utilised up to the present are the following:—

For land filling, *i.e.* raising the level of land.

For road bottoming.

For the manufacture of mortar with lime.

For the manufacture of concrete with Portland cement, the concrete being used either *in situ*, or for paving flags, kerbs, and a variety of other purposes, many of which have been demonstrated by the Corporations of Glasgow, Liverpool, Bradford, among other municipal authorities.

For making bricks.

Finely-crushed clinker is used in place of sand for the cushion bed of street paving, for grouting, and for "sanding" slippery surfaces. It can also be used for plaster work, and for a variety of purposes for which sand would ordinarily be employed.

For the construction of bacterial filters and contact beds at sewage disposal works.

For the manufacture of paving blocks with Trinidad rock asphalt.

While a considerable quantity of clinker has been used for land filling, it is but rarely used for this purpose unless it is of poor quality, or, owing to peculiar local conditions, difficulties are experienced in otherwise profitably disposing of the same.

With reference to its utilisation for the bottoming or foundation of roads, immense quantities of clinker are now being used for this purpose, and in rapidly growing towns the revenue derived from clinker used for this purpose is, and will continue to be, considerable.

Concerning the manufacture of clinker mortar, which method of utilisation has been extensively adopted, although about one hundred and fifty mortar mills are in use at destructor works, and in spite of the fact that the manufacture of mortar is profitable, to some extent local authorities are hampered by the attitude of the Local Government Board. Loans for the provision of mortar mills are usually not sanctioned by the Board unless a resolution is passed by the local authority to the effect that the mortar made will be used by the local authority, and not sold.[1]

[1] Some few local authorities have provided against this difficulty when promoting an "Omnibus" or General Improvements Act. Among such authorities are the Acton and Watford Urban District Councils. The following "standard" clause is embodied in the Watford Bill of 1909; any local authority promoting an Improvements Bill may secure the insertion of the clause without any difficulty.

Watford Urban District Council Act, 9 Edward VII., Session 1909.

Clause 91.—"The Council may convert any clinkers or other refuse or surplus material or product arising in connection with their refuse destructor into slabs of artificial stone, bricks, concrete mortar, and other materials, and may construct such buildings and works, and may, in connection therewith, provide and erect such machinery, plant, and appliance as may be required, and any such slabs, bricks, concrete mortar, or other materials so produced may be utilised by the Council for repaving streets, or for any other purposes connected with the work of the Council for which they may be suitable, *or may be sold by the Council, who shall carry the proceeds arising from any sales thereof to the credit of the district fund.*"

Such a resolution obviously tends to restrict the use of clinker for the purpose in question, as but few local authorities can use any considerable quantity of mortar. In order to overcome this difficulty, in towns where a good demand for mortar exists or is likely to exist, the authorities purchase and install mortar mills out of revenue, a course which, from more than one point of view, is the most desirable one to adopt.

Mortar has been made from destructor clinker for nearly twenty years past, and it is generally conceded that clinker mortar is a far better article than sand mortar. With sand practically the sole hardening effect is brought about by the absorption of carbonic acid gas by the lime. With clinker, however, this is not the case, as it possesses hydraulic properties of its own which are sufficient to induce a combination between its siliceous compound and the lime with which it is mixed.

In order to make the best mortar, the hardest clinker only should be used, but there is no necessity to reject the finer clinker, always provided that it is well burned, and that thorough grinding is insisted upon.

The most suitable lime is a fat or pure lime, and there is no appreciable gain in using hydraulic or lias lime if pure lime is obtainable. Pure lime will go further, and the clinker will give all the desirable hydraulic properties.

Generally speaking, excellent mortar can be made with the following proportions, which are expressed in weight, and are based upon dry clinker and unslaked lime:—

Lime .	10 parts	= per ton of mortar	2·1 cwt.
Water .	25 ,,	= ,, ,, ,,	5·2 ,,
	(three parts taken up by lime)		
Clinker .	60 parts	= per ton of mortar	12·6 ,,

Clinker crushing and screening plant and mortar mills are too well known to call for any description; it will suffice to say that the nature of the material to be treated is such that cheap crushing plant and mortar mills are quite unsuitable, and will involve a heavy maintenance account.

The crushing plant should be of the best design and of massive construction; the mortar mill must be of a heavy pattern, with fairly heavy rollers.

The Bradford Corporation have some twelve mortar mills in use, and derive a considerable revenue from the sale of mortar. A pair of mortar mills at Hammerton Street destructor works, Bradford, are

illustrated in fig. 51. At Blackpool, during the year 1909, 1710 tons of mortar were sold, realising the sum of £356, the cost per ton for labour and lime being 1s. $0\frac{1}{4}$d. and 1s. $3\frac{3}{4}$d. respectively, or 2s. 4d. per ton, and so great has been the demand for mortar that an extra mill has been installed.

The utilisation of clinker for the manufacture of mortar is bound to increase, although, unfortunately, owing to the fluctuating demand due

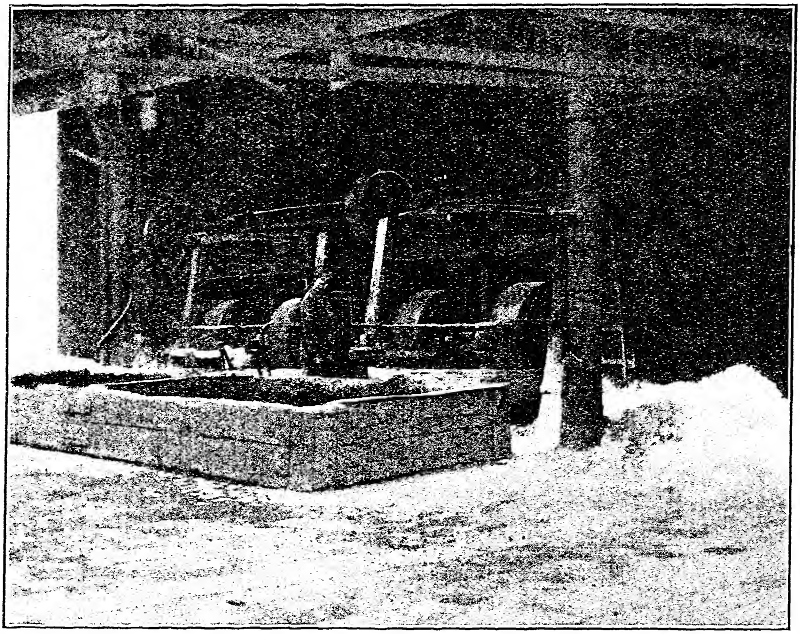

Fig. 51.—Mortar Mills, Hammerton Street Destructor Works, Bradford.

to the more or less intermittent character of building operations, the sale is not constant.

When crushed to a suitable size and mixed with Portland cement for making concrete, this may with advantage be used for practically any purpose for which concrete is used.

As long since as 1885, Mr Charles Jones of Ealing recognised the utility of clinker for the manufacture of artificial stone, and during that year, in the construction of the Ealing Isolation Hospital, the slabs, window sills, heads and mullions, as well as the wall copings, were made of clinker concrete.

In Liverpool, Glasgow, Bradford, in fact in all parts of the kingdom, considerable quantities of clinker concrete have been used for a variety

of purposes. In Bristol, building dressings made by hand in wooden moulds cost 2s. 8d. per cubic foot.

At Prahran (Melbourne), during 1910, Mr W. Calder, the city engineer, who has shown much enterprise in the utilisation of clinker, erected the new Corporation stables in clinker concrete blocks.

Mr Ernest Call, the energetic Cleansing Superintendent of the city of Bradford, commenting upon the use of clinker in that city, says:—

"There are now about fifty houses standing at Little Horton, Bradford, built with mortar, mixed with the shovel, from our fine clinker and lime; moreover, the causeways and backyards are paved with our clinker flags, the plaster on the walls is from our fine screened clinker, the dust bins were supplied by this department; in fact, with the exception of wood, some stone, and labour, we produced the houses from destructor bye-products."

Clinker Flags.—Not many years since, the idea of utilising clinker for the manufacture of paving flags was regarded as visionary, and not a little prejudice has been shown by some municipal engineers. Such authorities as Mr Charles Jones of Ealing and Mr H. Percy Boulnois have done much to demonstrate the value of clinker for this purpose, with the result that some thirty clinker flag plants have been installed at the following destructor works:—Fulham, Chiswick, Manchester, Nottingham, Oldham, Adelaide, Coventry, Liverpool (2), Bootle, Blackburn, Sheffield, Birmingham, Bristol, Bradford, Cheltenham, Southampton, Hornsey (2), Ealing, Walthamstow, Preston, Birkenhead, Barrow-in-Furness, Woolwich, and Bermondsey, etc.

At the Bristol Corporation destructor works, clinker concrete flags are made in a Musker flag plant at a cost of 2s. 6d. per yard, which sum includes capital charges, depreciation, and repairs. The daily output is about 97 super. yards in 9½ hours.

The following records in connection with these works are of interest:—

One ton clinker is required for 16 yards super. of flags.
One ton of granite chippings will face 60 super. yards.
For every 45 yards super. one ton of cement is used.

The usual mixture employed is three parts of clinker to one part of Portland cement. The flags are faced with granite chippings, in the proportion of two parts of chippings to one part of Portland cement.

Fig. 52 is a view of the flag plant at one of the Birmingham Corporation destructor works.

At two of the destructor works of the Liverpool Corporation no less than 53,684 super. yards of flags were made during the year 1909.

While the utilisation of clinker for this purpose is certain to increase,

yet the adoption of flag-making plant must obviously be confined to the larger cities and towns. The smaller municipalities do not favour this method of utilisation, as in many cases the clinker can be disposed of without any difficulty, while the quantity available does not warrant the necessary capital expenditure.

Clinker Bricks.—It is useless to disguise the fact that clinker brick-making up to the present time has failed to make any appreciable head-

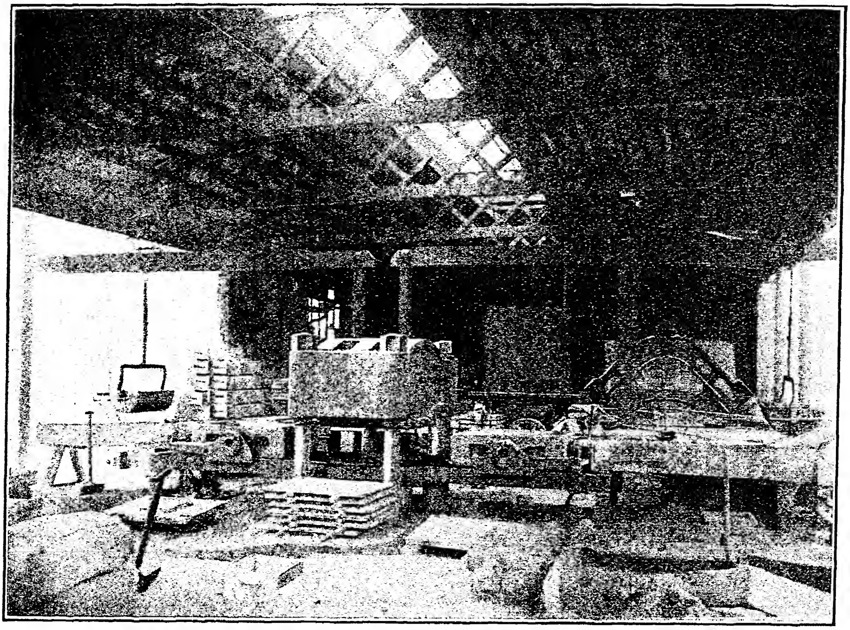

Fig. 52.—Birmingham Corporation Clinker Paving-Flag Plant.

way in England. When this method of utilisation was introduced some few years since it was anticipated that much would be done in the larger cities, and that the production of bricks from clinker would offer a new and profitable means for the utilisation of clinker in considerable quantities.

The principal reasons why it is impossible to record any really satisfactory progress in the adoption of clinker brickmaking plant may be briefly summarised as follows:—

(1) For some years past, owing to over-production and serious competition in the ordinary brickmaking industry, prices have been very low.

(2) Generally there is a hesitation on the part of local authorities to embark upon another competitive business under such conditions, even if a loan can be obtained for the installation of the necessary plant.

(3) The difficulty already referred to in obtaining borrowing powers (unless the municipality has such powers under a private Act), and the restrictions placed upon authorities by the Local Government Board.

Bearing in mind the very serious condition of the brick industry for some years past, it is fortunate that municipal authorities have been very cautious. That there is a good future for the clinker brick is practically certain; but had municipal authorities in any number installed brickmaking plant under such conditions as have obtained during the past few years, the results would have been so disappointing as to have seriously jeopardised the future.

Among the few municipalities in England possessing clinker brick-making plant are the Metropolitan Boroughs of Fulham and Woolwich (London), and the Corporations of West Hartlepool and Nelson.

At Woolwich and West Hartlepool the plant was installed by the Queen's Engineering Company of Leeds, while at Nelson the makers were Messrs Sutcliffe, Speakman & Co., Ltd., of Leigh.

At West Hartlepool, owing to serious depression in the building trade, the plant has not been in use for some little time past. This plant has a capacity of 5000 bricks daily, and when in use about 3000 bricks are made per day. Six per cent. of fresh lime has been used, and the cost per 1000 bricks made has averaged 16s. 6d., the selling prices being 19s. per 1000 for firsts and 16s. per 1000 for seconds.

Among purposes for which the bricks have been used at West Hartlepool are the erection of stables, and also extensions to the electricity works; for external work they are not generally recommended, but they are admirably adapted for inside lining.

Tests conducted by Messrs Kirkcaldy show the crushing strain to be 210 tons per square foot, and the absorption of water about 7 per cent. by weight.

The plant installed at Nelson comprises a ball mill for grinding lime, a 9-ft. perforated grinding mill for clinker, a clinker screen, patent hydrating mixer and final mixer, brickwork silos, an "Emperor" press, and a hardening chamber, having a capacity of 7000 bricks.

The plant is electrically driven; for grinding, an average of 28 H.P. is required, and for the final mixing and brickmaking, 12 H.P. The

quantity of clinker available at Nelson is only sufficient to permit of from 18,000 to 21,000 bricks being made per week, hence it is not possible to run the plant continuously.

On Friday, Tuesday, and Wednesday the clinker is ground, mixed, and deposited in the silos, while the bricks are made on Saturday,

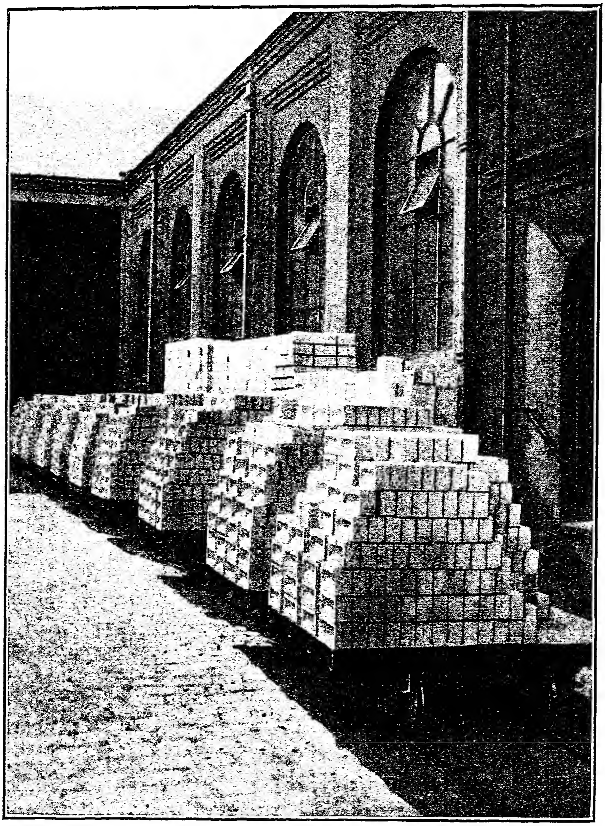

FIG. 53.—Nelson Corporation Clinker Bricks.

Monday, and Thursday. The steaming of the bricks is done during the night, steam being provided from the boiler in connection with the refuse destructor.

The labour required for making 18,000 bricks is three men, while $4\frac{1}{2}$ tons of lime are used. Fig. 53 illustrates clinker bricks at Nelson ready for sale. Tests made with bricks manufactured at Nelson gave the following results:—

TABLE XIII.

COMPRESSIVE STRENGTH.

Description.	Dimensions.	Base.	Stress in Pounds.		
			Cracked Slightly.	When Cracked Gen.	Crushed.
	Inches.	sq. in.			
Composition brick, grey, no recess, made from destructor clinker and 6 per cent. lime	2·77, 9·00 by 4·36	39·24	222·000	259·800	262·000
Do.	2·95, 9·02 by 4·40	39·69	199·900	230·800	248·000
Do.	2·80, 9·00 by 4·34	39·06	154·600	222·700	222·700
Do.	2·63, 9·02 by 4·36	39·33	150·900	206·000	206·000
Do.	2·62, 9·02 by 4·36	39·33	134·500	204·700	204·700
Do.	2·80, 9·00 by 4·36	39·24	130·600	159·000	159·000
	Mean	39·31	165·417	213·833	217·067
	Lbs. per sq. in.	...	4208	5440	5522
	Tons per sq. ft.	...	270·6	349·8	355·1

TEST FOR ABSORPTION.

Description.	Before Immersion.	After 24 hours' Immersion.	Difference.	Absorption.
	lbs.	lbs.	lbs.	per cent.
Composition brick, grey, no recess	9·330	9·679	·367	3·93 } 6·72
Do.,	8·510	9·273	·763	8·97
Do., recessed one side	8·573	9·195	·622	7·26

COMPARISON OF ANALYSES OF LIME BRICKS AND CEMENT CONCRETE.

Clinker and Lime Bricks made with about 8½ per cent. of Lime.	per cent.	Clinker and Cement Concrete made from 1 Cement and 5 Clinker.	per cent.
Lime	17·0	Lime	16·8
Silica	32·5	Silica	32·2
Alumina	14·8	Alumina	14·1
Ferric oxide	18·2	Ferric oxide	16·8
Magnesia and alkalies	5·5	Magnesia and alkalies	5·8
Water in combination	12·0	Water in combination	14·3
	100·0		100·0

The time required from the taking of the raw material to the delivery of the finished bricks ready for use is from 30 to 48 hours; the manufacture of ordinary clay bricks usually takes three weeks.

Mr H. Percy Boulnois[1] has expressed the opinion that the clinker brick is "equal to the well-known blue Staffordshire bricks, and that such a use for clinker should be encouraged and developed."

On the Continent, Dr Schultess of Zurich has devoted considerable attention to the development of clinker brickmaking plant. In Germany, Messrs Herbertz of Cologne are operating a very successful clinker brickmaking plant at Kiel, utilising the clinker from the destructor erected by them.

There are signs that England will be left behind by some of the Continental countries in the successful utilisation of clinker for brick-making unless a more rapid development takes place within the next few years.

The use of crushed clinker for bacterial filters or contact beds at sewage-disposal works has provided an outlet for immense quantities of clinker. For some years past, at least one contractor in London has handled upwards of 80,000 tons per annum, while many municipal authorities having destructors installed at sewage works have used considerable quantities, and in several instances have sold some thousands of tons direct to neighbouring authorities.

For filter beds the clinker should preferably be reduced to a cubical form and all dust should be screened out; it is also desirable that the iron and metallic substances should be separated.

After crushing, the clinker may be passed through a magnetic separator to take out all iron, and then screened to the sizes required.

The usual type of magnetic separator consists of a rotating drum with electro-magnets set all round the periphery. Upon the drum a steel belt runs, the clinker falls on to the belt, and is carried forward over the drum; the iron particles attach themselves to the drum, and travel round to the underside, where the belt, upon leaving the pulley, detaches the iron, which falls into a suitable receptacle; the clinker falls directly off the drum into a screen or hopper placed below.

Some interesting data concerning the utilisation of clinker at sewage-disposal works will be found in Tables I. and II.; it is generally conceded that good destructor clinker is the best material for bacterial filters and contact beds, and by utilising the same many local authorities have effected a considerable saving.

Clinker and Asphalte Paving Blocks.—For some years past experiments have been proceeding with a view to the utilisation of destructor clinker with asphalte for the manufacture of paving blocks.

[1] See paper read by Mr H. Percy Boulnois, M.I.C.E., at Health Congress, Cardiff, July 1908.

The experimental work has been carried out at the Borough of Kensington (London) destructor works, where, after much patient application, considerable progress has now been made.

Having in mind the fact that every satisfactory method of utilising clinker must possess an interest for those who are responsible for its disposal, a brief description of the plant installed at Kensington will doubtless be of interest.

The clinker is taken direct from the cells and fed into a powerful grinding mill, where it is ground sufficiently to pass a fine screen. The screened material is then fed, by means of horizontal pushers, into the lower part of a steel elevator, which is encased in steel sheeting, and is elevated to the first floor of the building, and passed through a shoot into a revolving steel dryer, where the screened clinker is subjected to an intense heat. Passing from the dryer, it is again elevated to the floor above, and is then fed into a measuring hopper having a bottom lever discharge. While this part of the process is taking place the ground asphalte is being prepared. The asphalte is hoisted to the top floor of the building and fed into large melting vats, which are of special construction, arranged with heating coils and a superheated steam supply for the melting of the asphalte and for maintaining the same at a high temperature. When in a suitable condition a supply of residuum oil is introduced.

From the melting tanks the mixture passes into a conical measuring vessel, when the desired volume is reached; this vessel is carried by means of a mono rail to the mixer, into which the ground clinker and asphalte mixture are simultaneously introduced and thoroughly mixed. The mixer is of strong construction, being made in steel boiler plate, and is provided with pug arms and substantial gearing.

When thoroughly mixed at an even temperature the material is discharged into a steel shoot which communicates with the block press.

The block press is of massive construction and exerts a pressure of 100 tons upon each block; the press is automatic in action; as one hopper is filled by the men in charge, another comes under the dies of the press, and as each block is formed it is pushed forward over a smooth iron table and conveyed to the cooling tank.

For the manufacture of 1000 paving blocks about 3½ tons of clinker is used with one ton of asphalte, the weight of the finished blocks being about 4 tons; the loss in weight is accounted for by the moisture. The cost per 1000 paving blocks is about £4 for materials and 14s. for labour.

It is claimed that the blocks are resilient, as noiseless as wood paving, non-porous, sanitary, and unaffected by temperature. Upwards

of one million of these blocks have been laid in Queen's Gate, Hyde Park, W., Ledbury Road, Bayswater, and in Stamford Street, near to the Royal Albert Hall, Kensington, W.

With the ever-extending use of destructors, the problem of clinker disposal must become increasingly acute. In the larger cities it is found necessary not only to install flag and mortar mills, but to carefully screen and grade the clinker with a view to meeting every conceivable demand.

In Liverpool during 1909, nearly 50,000 tons of clinker, rough and ground, was used in connection with building and other works.

During 1910, the Cleansing Department of the city of Leeds disposed of 10,000 tons of clinker, at prices varying from 1s. 3d. to 2s. 6d. per ton.

The enterprise of the Glasgow Corporation is well known to those interested in clinker disposal.

The following figures clearly indicate the possible revenue from residuals in connection with the cleansing department of a large city:—

TABLE XIV.

Glasgow Corporation Cleansing Department.

		Tons Sold.		Revenue.		
		Tons.	cwts.	£	s.	d.
Crushed and screened clinker	1900–1901	9,753	4¼	1095	1	10
	1901–1902	9,332	17½	977	7	7
	1902–1903	11,938	7½	1412	3	4
	1903–1904	15,292	0	1590	7	3
	1904–1905	14,693	0	1693	4	8
	1905–1906	17,635	0	2176	15	8
	1906–1907	13,975	10	1628	9	5
	1907–1908	13,307	3	1711	18	5
	1908–1909	13,807	2	1779	7	10
	1909–1910	11,768	13½	1582	6	3
Tins, galvanised buckets, and light iron	1909–1910	...		1791	0	0
Scrap iron	1909–1910	...		609	6	2
Waste paper	1909–1910	...		866	6	11

Taking the figures for the financial year 1909–1910, the total revenue from residuals was £4848, 19s. 4d., made up as follows:—

	£	s.	d.
Crushed and screened clinker	1582	6	3
Tins, light iron, etc.	1791	0	0
Scrap iron	609	6	2
Waste paper	866	6	11
Total .	4848	19	4

Tins and Scrap Metal.—Tins and scrap metal are, as a general rule, unprofitable residuals to the local authority. It is very desirable, and in many cases imperative, to get rid of the same as quickly as possible, and if the revenue therefrom is sufficient to cover the labour involved in sorting, loading, and in some instances cartage, this is all that can reasonably be expected.

The method of treating tins in the most up-to-date and scientific manner comprises two distinct processes:—

(1) Cleaning, desoldering, and compressing.

(2) Detinning.

The first process, which requires an extensive plant, and involves the use of much more labour than the second process, may be seen by those who are interested at the London Electron Works, Horseferry Road, Limehouse, London, E. The second process, which is of a more or less secret nature, is at present confined to the works in the German city of Essen.

At the London works already referred to upwards of 18,000 tons of scrap metal from house refuse are treated every year, of which about 15,000 tons comprise old tinned scrap material. Approximately 8000 tons are collected every year in London and the adjoining districts, the remainder being sent from all parts of England.

The material received may be divided roughly into three classes:—

(1) Tinned material only.

(2) *Mixed* material, comprising tins, galvanised, enamelled, and light iron scrap, wire, etc.

(3) So-called *rough* material, consisting of galvanised, enamelled, and light iron scrap and wire.

The tinned and mixed scrap (1 and 2) are unloaded immediately upon arrival at the works on to a perforated conveyor, which extends from the yard into the building, and is about 60 ft. in length. Alongside of the conveyor men are stationed, who pick from the conveyor as it travels past them everything which does not come under the category of "tinned scrap"; the material which enters the building by means of the conveyor is thus practically confined to "tinned scrap," comparatively free from dust and ashes, the latter having dropped through the perforations in the conveyor.

From the conveyor the tins immediately pass into a perforating machine, the object of which is to so perforate the tins that in the later chemical treatment the liquid used shall be able to freely penetrate through them.

Underneath this machine is a second conveyor, which takes the tins

to an elevator, which in turn feeds the same into the main cleaning and desoldering apparatus. At the inlet end, this apparatus consists of a large perforated drum, which revolves in a thin solution of hot caustic soda. Here the tins are freed from any foreign substance such as fat, paper, dust, food remains, etc. This process occupies nearly one hour, after which the tins are automatically delivered into a second and similar drum which revolves in an empty tank, and has for its object the draining of all superfluous liquid from the tins. Leaving this drum, the tins pass into another drum, which revolves in clean cold water; this process occupies but a short time; the tins then pass into a further drum for draining, and through this drum the hot exhaust gases from the desoldering furnace travel, and quickly dry the tins.

Being now in a suitable condition for desoldering, the tins pass into the final drum in which this process takes place. The desoldering drum revolves in an iron casing, heated by means of producer gas to a temperature sufficiently high to melt the solder adhering to the tins. At its extreme end this drum is open, and the desoldered tins fall on to a platform, under which is a hydraulic press. The material, which is now perforated, cleaned, and desoldered, is at once pressed into briquettes, and is ready for the second or detinning process, which, as already mentioned, is carried out at Essen.

The second process is known as the chlorine process, which requires somewhat complex and delicate apparatus, and can only be profitable when conducted on a very large scale. At the Essen works upwards of 80,000 tons of tinned scrap are being treated every year.

The chlorine process may be briefly described as follows:—The desoldered briquettes are put into a large iron cylinder, which is hermetically sealed, and from which the atmospheric air has been exhausted. The cylinder is then filled with pure chlorine gas, which is forced in under pressure, and which penetrates the innermost recesses of the compressed briquettes. The chlorine gas greedily absorbs every particle of tin, and combines with the tin to form the well-known chloride of tin ($SnCl_4$), for which chemical there is a ready market in the silk-dyeing industry.

Having been thus treated, the briquettes are absolutely free from tin, and now represent pure mild steel, for which there is a good demand by all the best steelworks.

It is a common fallacy that tins having passed through a fire lose their covering of tin, and are in a suitable condition for melting again in open-hearth furnaces.

There are some few local authorities in England who pass their tins

through furnaces, then compress the same into briquettes, and put the material on the market as *detinned scrap*. Innumerable analyses have shown that tin is not entirely removed by heating, and much of the so-called "detinned scrap" is not at all suitable for the manufacture of steel.

After passing through the rigorous cleaning and desoldering process already described, it is found that the percentage of tin left on the scrap invariably exceeds 1½ per cent.

It will be clear that the processes described are such that it would not pay any municipal authority to embark upon, because of the small percentage of this residual.

At many destructor works tin baling presses have been installed; in reducing the bulk and facilitating the handling and removal of this residual the baling press is very useful, but apparatus of this kind is unnecessary, excepting in the larger cities and towns.

At Blackpool the cost of labour for pressing and loading the baled tins into trucks is about 7s. per ton, while 15s. per ton is obtained for the tins at the destructor works. During 1909 the revenue from tins was £85, the weight of tins sold being 131 tons 9 cwts. The Bradford Corporation cleansing department dispose of about 170 tons of tins per annum at 15s. per ton. The Torquay Corporation obtain 17s. 6d. per ton for tins delivered at Torre station

Such cases might be multiplied; tins are no longer a source of trouble and expense, the revenue therefrom in every case is sufficient to cover all expenses in handling, and in some cases a small profit remains.

Fish Offal.—In connection with some of the larger destructor works in England it has been found profitable to install plant for the conversion of fish offal into manure.

While such material can be destroyed without any difficulty along with the ordinary refuse, as is the daily practice at the majority of destructor works, there is a growing tendency in the larger cities and towns to arrange for the separate delivery of fish offal at the works in galvanised bins, and for its immediate conversion into manure.

The usual type of fish manure plant consists of an inner and outer cylindrical shell, the inner cylinder being fitted with radial arms fixed to a central shaft, which may be driven by an electric motor or otherwise, as may be most convenient.

The fish refuse is fed into the inner cylinder and is broken up by the revolving arms. The space between the inner and outer cylinder, which is usually about 2 in., is supplied with steam at a pressure of about 100 lbs. to the sq. in., which drives off the moisture, the vapour being led away to the main combustion chamber.

After being thoroughly broken up and dried the manure is passed through a mill and crushed to an even size, about the consistency of oatmeal; it is then put into sacks and is ready for sale. It takes 4 tons of crude fish offal to produce 1 ton of manure. The cost of manufacture is about £1 per ton, while the market price is about £4 per ton, and the demand far exceeds the supply.

At Blackpool the revenue from this source is nearly £500 per annum. Plant has been installed at Liverpool, Bradford, Chorley, and several other cities and towns. At Bradford the demand is very heavy, and it is claimed that there would be no difficulty in disposing of ten times the present output.

Paper.—Within the past few years there has been a disposition upon the part of the larger municipalities, such as Liverpool and Glasgow, to encourage the separation of paper from the refuse in the business quarters of the city, with the result that wastepaper has now become a source of revenue. During 1909, in Liverpool, 378 tons of paper were sold to papermakers, while during the year 1909–10 the Glasgow Corporation realised the sum of £866, 6s. 11d. from the sale of paper.

CHAPTER XI.

FOREIGN AND COLONIAL PRACTICE.

THOSE who have closely followed the developments in refuse disposal will be aware that considerable progress has been made on the Continent during the past few years.

With the exception of those in Germany, Austria, and Hungary, most of the destructors now in operation on the Continent are of British design. It would, however, be foolish to disregard the fact that much attention has and is being devoted to the combustion of refuse by German engineers.

To what extent this will affect future Continental work remains to be seen; certain it is that in Germany alone sufficient remains to be done to provide an immense amount of work for many years to come, and the present indications are that the future of refuse disposal in Germany will be in the hands of the German destructor makers, and that it will be exceedingly difficult, if not absolutely impossible, for the British makers to compete, with any hope of success.

In order to avoid any misconception, it may be observed that competition in Germany does not resolve itself into a critical comparison of tenders, designs, and guarantees; there are obviously other factors which will weigh heavily. No good purpose can be served by discussing the same; collectively, if not individually, they present insuperable difficulties.

The British makers have already recognised the impossibility of competing in Germany. In other Continental countries, where competition with the German makers will become more or less acute, those factors which in Germany must operate against the "outsider" will not obtain under such conditions.

When the determining factors are design, guarantees, reputation, and price, the British maker will compete under fair, even if not under favourable, conditions.

The work done in Continental countries is set forth in the following Table XV. While the tabular statement covers a period of fifteen years, most of the works have been erected during the past ten years.

TABLE XV.

France.	
Paris[1]	Meldrum top-fed.
St Etienne	" "
Havre	Heenan back-fed.
Rouen	" top- "
Elbeuf	Herbertz " (German).
Monaco	Horsfall "
Toulon	Destructor and pulveriser (French).
Marseilles	" " " "
Nancy	Heenan.
Trouville	" back-fed.
Belgium.	
Brussels (Quai de la Voirie)	Horsfall top-fed.
" St Gilles . .	Meldrum "
" Ixelles . . .	Heenan "
" Molenbeck St Jean	Destructor and pulveriser (French).
Holland.	
Rotterdam	Heenan mechanically-fed.
Denmark.	
Frederiksberg (Copenhagen)	Sterling top-fed.
Russia.	
St Petersburg . . .	Horsfall tub-fed.
" " . . .	Heenan top- "
Czarskoe Selo . . .	Horsfall " "
Warsaw	" tub- "
Odessa	" front-fed.
Switzerland.	
Zurich	Horsfall tub-fed.
Germany.	
Hamburg	Horsfall top-fed.
"	Caspersohn's top-fed (German).
Cologne	Herbertz " "
Frankfort	" " "
Kiel	" " "
Wiesbaden	Dörr " "
Beuthen O. S. . . .	"
Segefeld bei Spandau . .	"

[1] A Heenan destructor of the mechanically-fed type, having a destroying capacity of 480 tons daily, is now in hand.

Austria.	
Fiume	Herbertz top-fed (German).
Pukheim (Munich)	" " "
Abazzia	" " "
Lovrana	" " "
Hungary.	
Miscolz	Dörr " "
Italy.	
Bologna	" " "
Genoa	Destructor (German type).
Spain.	
Gibraltar	Meldrum back-fed.

In a recent lecture delivered before the Hungarian Society of Engineers by Herr Etienne de Fodor, general manager of the Buda-Pest General Electric Company, he stated that the following results had been obtained in evaporative tests with refuse in Continental cities:—

	Pounds of Water per Pound of Refuse.
Barmen	1·30
Mainz	1·30
St Petersburg	1·16
Fiume	1·03
Kiel	1·05
Frankfort	1·00
Copenhagen	0·92
Hanover	0·91
Amsterdam	0·90
Christiania	0·89

With the exception of St Petersburg, these figures would appear to be correct. Up to the present time one destructor only is in operation in that city, and the evaporative tests in connection therewith showed an evaporation per pound of refuse of about ·3. Those who have seen the refuse of St Petersburg will agree that such a figure, as given by Herr Etienne de Fodor, is quite impossible.

With the exception of Russia, and more particularly Northern Russia, all the available data go to show that the results which may be obtained in power production in Continental countries will often compare favourably with the average results obtained in England.

While this has been established, it is also perfectly clear that the British destructor, as designed for use in England, requires modification to satisfactorily meet Continental requirements, and those who would be in a position to compete on the Continent must closely study the conditions obtaining in the various Continental countries.

It may be observed as a general rule that steam-jet blower draught is unsuitable for Continental refuse. Fan draught, with a regenerative system of hot air, is absolutely essential.

FRANCE.

Paris.—For some years past the bulk of the refuse of the city of Paris has been disposed of by companies to whom concessions have been granted by the municipality. The disposal works are located in the districts of Vitry, Issy les Moulineaux, St Ouén, and Romainville. The refuse of four arrondissements has been delivered to the works controlled by the Société générale des Engrais Organiques, while the refuse collected in twelve other arrondissements has been delivered to the three works controlled by the Société des Engrais complets.

The refuse collected in four arrondissements not included in the concessions above referred to has been either barged or carted out of the city and deposited on waste land.

Some months since the municipality decided to institute changes in the present organisation for the disposal of the refuse of some five arrondissements. It was decided to adopt the disposal system of the Société générale des Engrais Organiques in connection with the refuse of the five arrondissements in question. The disposal system of this company is described as a "mixed system": instead of confining their attention solely to the pulverisation of the refuse and the production of manure, as hitherto, the refuse is sorted with a view to burning the combustible portion and pulverising the organic waste, while the system also provides for the burning of the whole of the waste without preliminary sorting should this for any reason be found desirable.

This, which is now known in France as the "mixed system," *i.e.* pulverising and cremation, has been adopted in Toulon, Marseilles, Molenbeck, St Jean (Bruxelles), and Alexandria.

In Paris it is proposed to erect a new works for this purpose at Ivry, which will take the place of the existing works at Vitry already referred to. It is also proposed to make such changes in the existing works at Romainville as may be necessary in order to adopt the "mixed method" of disposal. Further, a new destructor works is to be erected at Gennevilliers.

In the future the refuse collected in the 1st, 6th, 7th, 8th, and 16th arrondissements will be delivered at the Gennevilliers works, and the whole of this will be destroyed. The refuse collected in the 2nd, 9th, 17th, and 18th arrondissements will be delivered at the St Ouén works.

At the Issy les Moulineaux works the refuse from the 14th and 15th arrondissements will be delivered.

At the St Ouén and Issy les Moulineaux works the "mixed system" will be employed. The refuse collected in the 3rd, 10th, 19th, and 20th arrondissements will be delivered to the Romainville works, while to the new Ivry works will be sent the refuse collected in the 4th, 5th, 11th, 12th, and 13th arrondissements. These works will be controlled by the Société Fermière de la Voirie de Paris, and the "mixed method" of disposal will be adopted.

In the "mixed method" it is recognised that the component parts of refuse are such that certain portions have a manurial value, while other portions are valuable owing to their calorific value; and as it is felt that nothing should be wasted, the combined system of pulverising and cremation has been introduced.

While the French are unquestionably a utilitarian people, there are other reasons why the "mixed system" has been adopted; these reasons it is unnecessary to discuss at length, but they may be briefly stated as follows:—

(1) The increasing difficulty of finding a constant and profitable market at all times for the poudro (manure). (2) The difficulty of disposing of refuse at such times as the demand for the poudro slackens.

The type of pulveriser used for the treatment of the Paris refuse is practically the same as that in use at Southwark, London. The poudro produced by the Société générale des Engrais Organiques is said to have given the following result when analysed:—

Nitrogen	6	to	10	kilos	per ton.
Phosphoric acid	6	,,	9	,,	,,
Potassium	4	,,	10	,,	,,
Lime	40	,,	60	,,	,,
Organic matters	300	,,	500	,,	,,

Under the "mixed process" it is claimed that the portion extracted and remaining to be destroyed will be fully twice as valuable from a steam generating point of view than would be the case if the whole of the material collected were destroyed without sorting.

Tests conducted at Vitry by the Association Parisienne de Propriétaires des Appareils à Vapeur, before representatives of the Technical Service of the Municipality of Paris in February 1909, showed that one kilogramme of refuse would evaporate 1·800 kilogrammes of water, as will be seen from the following Table XVI.:—

TABLE XVI.

Tests at Vitry Works, Paris, with a Semi-tubular Boiler, having 200 square metres of Heating Surface, fired with Gases from a Godillot Refuse Furnace.

Dates of Tests.	3rd Feb. 1909.	4th Feb. 1909.
Beginning of test	8.55 a.m.	8.50 a.m.
End of test	4.55 p.m.	5.04 p.m.
Duration of clinkering (minutes)	30 (from 12 to 12.30).	44 (from 12 to 12.44).
Duration of test (hours)	7.50.	7.50.
Large refuse (various objects) burned	405 kgs.	394 kgs.
Ordinary refuse burned { 3rd Feb. 311 buckets of 17·40 kgs. each	=5,411·40 kgs.	
Ordinary refuse burned { 4th Feb. 304 buckets of 17·37 kgs. each	= ...	5,280·50 kgs.
Total	5,816·40 kgs.	5 674 50 kgs.
Water evaporated	10 m³. 527.	10 m³. 550.
Average steam pressure	5·48 kgs.	6·34 kgs.
Corresponding temperature	161° C.	166° C.
Temperature of feed water	12° C.	12° C.
Evaporation per hour	1,403·60 kgs.	1,406·66 kgs.
,, ,, m² surface	7·02 kgs.	7·03 kgs.
Steam raised per kg. of refuse	1·81 kgs.	1·86 kgs.
Efficiency in water at 0° and steam at 100° C.	...	...
$R' = \frac{606 \cdot 5\ 0{,}305 \times T - t\ R}{606 \cdot 5\ 0{,}305 \times 100}$	1·83 kgs.	1·88 kgs.
Temperature in the Godillot furnace	850° C.	850° C.
Temperature of gases after leaving the boiler	240° C.	240° C.
Pressure in the furnace	2·5 mm.	2·5 mm.
Composition of refuse { Moisture	28·70 per cent.	
Volatile matter	32·60 ,, ,,	
Ashes	21·40 ,, ,,	
Fixed carbon	17·30 ,, ,,	

Calorific power (by Mahler bomb) 2·534 cal.

In connection with the Ivry and Romainville Works, it is anticipated that after supplying all the electrical energy required at these works for various purposes, some 1800 units per hour will be available, and that this current will be disposed of to the municipality.

While the "mixed" process may offer some solution of the difficulty, there is no doubt, in fact it is admitted, that within recent years it has become increasingly difficult to find a market for the manure, and it is very significant that even in connection with the works where the "mixed system" has and will be adopted the capacity of the destructors installed will be such as to enable the whole of the refuse delivered to be destroyed whenever this may be desirable.

The refuse destructors erected, and now operating, in Paris, are of the Meldrum top-fed type, and are located at the disposal works already referred to,—St. Ouén on the north, Romainville on the east, and Issy les Moulineaux on the south-west of the city.

Each installation comprises three 4-grate units, each having 100 square feet of grate area, and three Babcock & Wilcox boilers, with regenerators and bye-pass flue; the chimney at each work is 30 metres in height.

The total destroying capacity of the three installations is about 650 tons daily. At the St Ouén and Romainville works, the power is utilised in the works, while at Issy les Moulineaux the steam is fully utilised in connection with H.T. three-phase generating plant.

Monaco (Fonteville).—Here is a Horsfall top-fed destructor of 4 cells, erected in 1898. One water tube boiler having 75 square metres of heating surface was installed to provide steam for forced draught and works purposes. The chimney is 35 metres high and 1·30 metres internal diameter. This was the first destructor erected in France. Among recent installations are the following:—

Havre.—Here a destructor of the Heenan back-fed type has been erected, the capacity being about 150 tons daily; the power is fully utilised for sewage works purposes.

Rouen.—A Heenan top-fed destructor having a capacity of 150 tons daily, has been erected here.

St. Etienne.—A destructor of the Meldrum top-fed type, comprising eight cells, has been decided upon.

Elbeuf.—A small destructor has been erected here by Messrs Herbertz of Cologne.

It is interesting to observe that in France, where so much attention has been devoted to the conversion of refuse into manure, and with considerable success, the present tendency is to provide refuse destructors. To those in England who are inclined to think that the pulverisation of refuse will offer a solution of the disposal problem the experience in France should appeal.

For some few years past the only serious alternative to disposal by fire has been the conversion of refuse into manure. That this is no longer a serious alternative is demonstrated by the present practice in France. As already observed, the decision of the French Refuse Disposal Companies to provide destructors is mainly due to the increasing difficulty in disposing of the manure. Those in England who have been disposed to regard refuse pulverising as the last word in disposal would do well to carefully reconsider the whole question, bearing in mind that what has happened in France would be more than likely to happen in England.

Is it to be supposed that where a powerful and well-organised company experience difficulty in disposing of manure, a municipal authority, embarking upon a new business, with no selling organisation, is likely to succeed?

BELGIUM.

The first destructor erected in Belgium was of the Horsfall top-fed type, at Brussels (Quai de la Voirie), 1901. To some extent the general design of the installation is similar to the Hamburg destructor. The twenty-four top-fed cells are arranged in two blocks back to back, the refuse is lifted and transported by means of electric cranes. Four water-tube boilers are installed, and the steam is fully utilised for the generation of electricity. Forced draught is provided by motor-driven fans. The chimney is 45 metres in height, and the internal diameter is 250 centimetres. Complete plant for cooling, crushing, and screening the clinker is provided.

TABLE XVII.—TABULATED RESULTS OF OFFICIAL TESTS OF THE "HEENAN" PATENT REFUSE DESTRUCTOR FOR THE COMMUNE OF IXELLES (BRUSSELS).

	Tests 7th–8th Oct.		Tests 9th–10th Oct.		Guarantees given.
Duration of test	11 h. 6 m.		9 h. 3 m. 30 s.		
Weight of refuse burnt per hour per 6 cells	35·30 tons		36·5 tons		
Equivalent rate of burning per 24 hours per 12 cells, deduced from above figures	169·5 tons		175 2 tons		115 tons
Weight of water evaporated per kilo of refuse burnt	·975 K°		1·245 K°		·75 K°
Mimimum temperature degrees in Centigrade	688° C.		800° C.		675° C.
Maximum temperature in degrees Centigrade	1040° C.		1064° C.		
Average temperature in degrees Centigrade	874° C.		920° C.		
	Sample.		Sample.		
	1st.	2nd.	1st.	2nd.	
Composition of the gases—	per cent.	per cent.	per cent.	per cent.	
CO_2	8·15	8·10	7·90	8·11	
O (free)	10·15	3·90	12·33	10·74	
CO	0·00	0·00	0·00	0·00	
N, etc., by difference	81·70	88 00	79·77	81·15	
Weight of clinkers and residues in percentage of the weight of refuse burnt	38·9 per cent.		38 per cent.		

The conclusions drawn from these results are, that during these tests the guarantees have been considerably exceeded, and that, with regard to the technical part of the plant, definite acceptance of the works may be proceeded with.

It is, of course, understood that these severe tests made exceed the normal working of the plant, and that the commune has not to expect to obtain, regularly, such results as to the number of tons of refuse to be burnt; besides, the contractors, who have had great experience, have only guaranteed to burn 115 tons of refuse in 24 hours, a quantity which will be very easily destroyed, and even exceeded, as proved by these tests.

IXELLES, 14*th October* 1908.

During 1907–8 destructors were erected at St Gilles and Ixelles, two communes on the outskirts of the city of Brussels. At St Gilles the destructor is of the Meldrum top-fed type, consisting of two 3-grate destructors, with two water-tube boilers and regenerators. Forced draught is provided by means of steam-jet blowers.

The Ixelles destructor is of the Heenan back-fed type, arranged in two units of six grates each, with a water-tube boiler for each unit. Fan-forced draught is used in conjunction with regenerators of the usual type.

The figures of the official tests (Table XVII.) in connection with this installation clearly show that a well-designed British destructor, when satisfactorily operated, is capable of giving very good results. Generally the Belgian refuse is of low calorific value, and an evaporation of approximately 1 kilo of water per kilo of refuse is the best that can be obtained, even under favourable conditions.

SWITZERLAND.

One destructor only has been erected in Switzerland, for the city of Zurich. Originally of the Horsfall top-fed type, it was completed in 1903, and five years later was converted for tub feeding. Two Babock & Wilcox boilers are installed. The chimney is 200 ft. in height, and 6 ft. 6 in. internal diameter. The steam is fully utilised for electrical purposes.

HOLLAND.

In Rotterdam, a mechanically-charged destructor, which will have a capacity of 450 tons daily, is just now in course of erection by Messrs Heenan & Froude, Ltd. The steam will be fully utilised for electrical purposes. This is the first destructor installation in Holland.

DENMARK.

In this country one destructor only has been erected—at Frederiksberg, a suburb of Copenhagen. The destructor, which is of the "Sterling" top-fed type, was erected in 1903, and consists of twelve cells, arranged in three units of four cells each, with one Babcock & Wilcox boiler to each unit, having about 2500 sq. ft. of heating surface.

Forced draught is provided by means of three direct-coupled motor-driven fans, working in conjunction with suction regenerators. The total capacity of the destructor is from 180 to 200 tons daily; the steam is fully utilised for the generation of electric energy for use at the works, power and light being supplied to a large hospital adjacent. Steam is

also supplied to the hospital for washing, cooking, disinfecting, and heating. The steam mains to the twenty-four large hospital blocks have a total length of about one mile, and are carried in a ferro-concrete conduit.

Fig. 54 is a view of the cells at Frederiksberg at the clinkering floor.

Exhaustive tests made in connection with this installation have shown very good results, notwithstanding the low calorific value of the

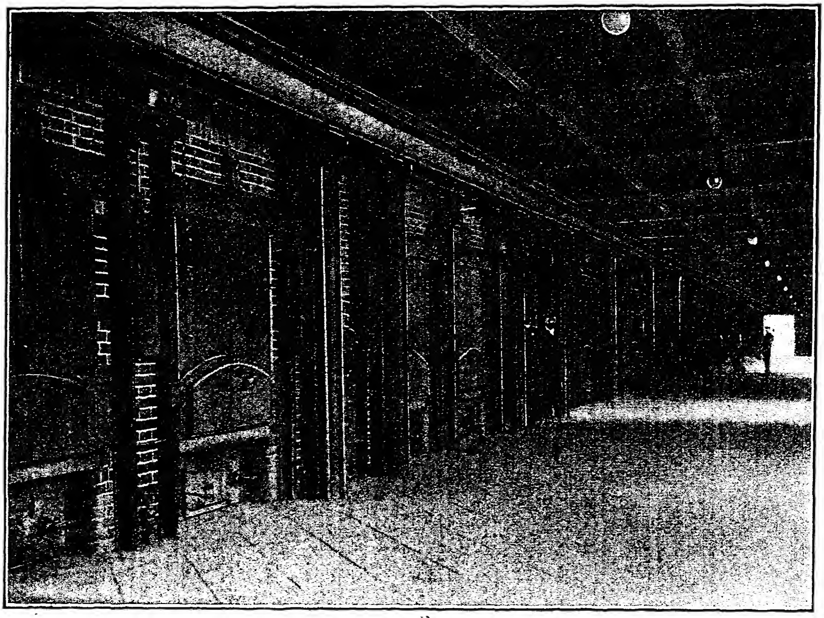

FIG. 54.—Frederiksberg (Copenhagen) Destructor, view of cells.

refuse; an average evaporation of $\frac{3}{4}$ lb. of water per pound of refuse destroyed has been obtained over a period of twelve months.

GERMANY.

The first recorded experiments in the burning of German refuse in destructors were carried out in Berlin in 1895, following investigations in England by Messrs Bohn and Grohn on behalf of the municipal council of Berlin. The sum of 100,000 marks having been voted for experimental work with Berlin refuse, three cells of the Warner top-fed type were erected, as also three cells of the Horsfall back-fed type, the

former being provided with fan-forced draught, and the latter with both steam-jet blowers and fan draught.

Owing to the high percentage of fine ash and dust in the refuse, the results obtained were not considered entirely satisfactory, and the installation was not extended.

It is but fair to bear in mind that these experiments were made some sixteen years since, with furnaces not specially designed for dealing with a very low grade of refuse. Further, it may be observed that these were the first British furnaces erected on the Continent. The important and very successful installations since in France, Belgium, Switzerland,

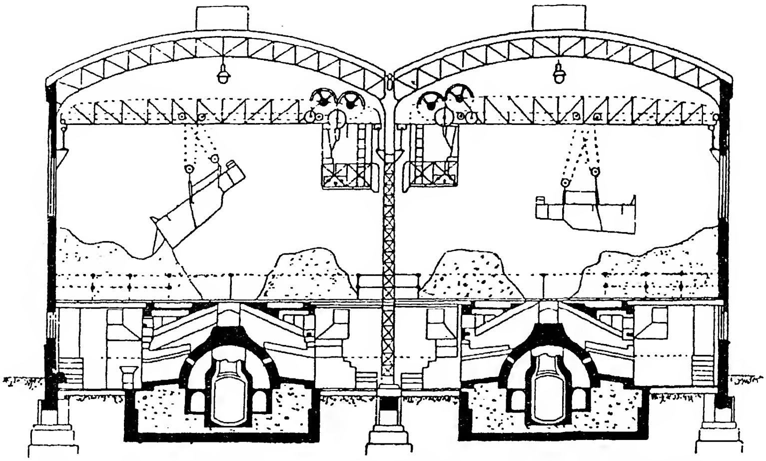

Fig. 55.—Horsfall's Top-Fed Destructor at Hamburg. Cross-sectional view.

Denmark, Russia, and many other countries all serve to show that much has been learned since the Berlin experiments.

In 1895, immediately after the experiments in Berlin, a large destructor of the Horsfall top-fed type was erected in the city of Hamburg, on the Bullerdeich. This installation comprised thirty-six cells, with multitubular boilers and fan-forced draught; the cells were back to back. The refuse was delivered to the works in vehicles having removable box bodies, each box having a capacity of 4 cubic metres. The boxes were hoisted and transported by means of electric cranes, the contents being tipped on to the top of the cells. The chimney is 160 ft. high and 8 ft. internal diameter. The steam is fully utilised with engines of a total of 260 H.P. Fig. 55 is a cross-sectional view of the Hamburg destructor.

The installations in Berlin and Hamburg represent all that has been done by the British makers in Germany. During the past ten years

there has been a revival of interest in sanitary refuse disposal in German cities, and some few engineers have devoted much time and study to the problem, but, on the whole, progress has been very slow.

Perhaps the best known destructor of German make on the market at present is the Herbertz. In addition to an experimental plant at Cologne, Herbertz destructors have been erected at Kiel and Frankfort, in Germany, Pukheim near Munich, Fiume, Abbazia, and Lovrana, Austria, and Elbeuf in France.

The installation at Cologne comprises five separate grates or cells, with a combustion chamber common to all arranged at the rear; the gases passing from the grates traverse the combustion chamber, and then pass through two water-tube boilers. The grates are small, each having an area of about 27 in. sq. only, and consist of perforated plates arranged for high-pressure fan draught.

The five cells or grates all face a common clinkering floor, above which is arranged a spacious sheet-iron storage bin, the base of which slopes at an angle of about 45° to the top of the cells. The refuse is lifted into this bin by means of a vertical conveyor. At the bottom of the inclined base of the storage bin, and forming one side of the bin, is a wall, and about 3 ft. from this wall, and parallel with it, is another wall. Between these two walls steel shoots are arranged, which communicate with openings through the top of the cells to the grates beneath.

A top chargeman on a platform above the combustion chamber rakes the refuse down from the bin into the shoots, which are always kept filled with refuse. The discharge of the contents of a shoot into a cell is effected by means of a sliding door in the shoot, and it is worthy of note that this operation is performed from the clinkering floor. The top chargeman is warned by means of a signal whenever the contents of a shoot are discharged.

The usual charge at Cologne is about one cubic yard of refuse, this being the capacity of the shoot. When this charge is in the cell the depth of material on the grate is about 4 ft., and it is found that a draught pressure equal to 12 in. of water is required. Each cell has a capacity of about 10 tons of refuse per 24 hours; the combustion chamber temperature varies from 1200° to 2000° Fahr.

The type of charging device is of much interest; it is, of course, possible to reduce the capacity of a charge if it is found desirable, and the top chargeman is also able to grade the refuse into the shoots to some extent. As the actual charging operation and the opening of the charging door takes place between two walls, any escape of gases is confined to this space.

A test over a period of thirty hours at Cologne gave the following results:—

Number of cells in use	3
Total weight of refuse destroyed	26,880 kilos.
Rate of combustion per hour	896 „
„ „ „ sq. ft. of grate per hour	40 „
Percentage of clinker	46 per cent.
Evaporation per pound of refuse (actual)	1·12 kilos.
Combustion chamber temperature	maximum 1070° Cent.
Average temperature of gases at chimney base	300°–410° „
Percentage of CO_2 in gases	average 15 per cent.

The Herbertz destructor at Kiel, which has now been in operation since the end of 1906, comprises three separate units, each consisting of six cells, with a combustion chamber and water-tube boiler. The grate area of each cell is about 3 ft. square. Above each unit is a spacious storage bin, having a capacity of about 100 cub. yds. The daily rated capacity of this installation is 185 tons, and the average quantity destroyed is 125 tons.

The system of refuse collection at Kiel is regarded by many authorities as closely approaching the ideal. All refuse is deposited by householders in cylindrical galvanised iron bins or cans, which are collected on a special two-horse waggon, capable of carrying forty-two bins. At the destructor works eight women are employed to cleanse and sterilise the empty bins.

The refuse wagons approach the works by means of an inclined roadway, and the bins are all unloaded on a platform at the elevation of the top of the storage bins, which are very similar to those at Cologne. The tops of the storage bins are entirely enclosed, and each storage bin is fitted with a closed hopper, which is arranged to receive the refuse cans and to discharge their contents into the bins below. This arrangement is clearly shown in the cross-sectional view of the Kiel installation, see fig. 56.

The charging shoots at the base of the storage bins are similar to those already described in connection with the Cologne destructor. The striking feature of the installation at Kiel is the fact that from the time the refuse is placed in the collection bins by the householders until the clinker finally emerges from the cells no refuse is exposed to view.

After the refuse is discharged into the storage bins twenty-four men are required to operate this plant, including two machinists and two boiler attendants.

Much ingenuity has been shown by the Herbertz Company in working out some of the problems involved in mechanical charging,

and no doubt in the near future some further developments will be seen on these lines. Considerable attention has also been devoted to mechanical clinkering, and at least one installation embodying a mechanical clinkering device is now operating.

For some years past Herr Caspersohn of Hamburg has been carrying out exhaustive experiments with a view to perfecting a system of mechanical charging. Herr Caspersohn's experimental cell, erected at Hamburg, may be briefly described as follows:—

The grate area of the cell is 1 square metre; between the cell and the main flue a large dust catcher is arranged in the form of an inverted cone, fitted with a sliding door at the base, and set sufficiently high for the passage of a car beneath, for the reception of the intercepted dust.

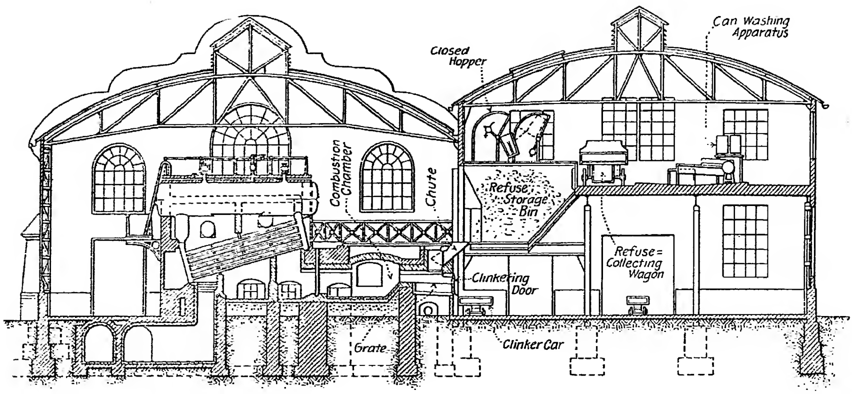

Fig. 56.—Herbertz Destructor at Kiel. Cross-sectional view.

The idea is to provide a separate dust catcher for each cell, and this is found to be necessary, because the high-pressure forced draught common to all destructors of German design has the effect of carrying forward an abnormal quantity of dust towards the main flue.

The arrangement of the dust catcher is shown in fig. 57, and it will be observed that it is so designed as to intercept a considerable proportion of the heavy dust carried in suspension.

The furnace walls are arched, and the charging door is arranged directly above the grate, this door being equipped with the mechanical device for delivering the refuse on to the grate.

The charging device consists of a long iron drum, sliding inside of a shorter concentric drum of considerably larger diameter. These drums fit into a conical sheet-steel funnel built into the brickwork at the top of the furnace. The two drums and the funnel form two annular

triangular spaces between the vertical sides of the drums and the sloping surface of the funnel.

The upper of these annular spaces opens at the floor level, and the fireman rakes or shovels refuse into it from the adjacent storage platform. The raising of the larger drum allows the refuse to fall into the lower annular space. The outer drum is then replaced, and afterwards the contents of the lower space are dropped directly into the cell by raising the smaller drum. Under these conditions the operation of charging the cell is performed without the possibility of any inrush of cold air, while there is no escape of hot gases from the furnace.

In connection with this experimental cell a large open platform was arranged over the furnace, the refuse being stored on this platform, and from it raked or shovelled to the charging device. The drums are raised and lowered by means of a differential pulley operated by the man on the storage platform.

This charging device possesses the merit of simplicity, and has but few moving parts, while with a suitable storage platform it permits of the refuse being mixed or graded, in addition to which the capacity of the charge may, within certain limits, be varied at will. The usual charge is 1 cubic yard, and this, when deposited on the grate, is about 3 ft. in thickness and fairly level. This charge is burned in about half an hour; it is estimated that the labour required for the operation of two cells, is one man on top and one man on the clinkering floor.

In the lay-out of a number of cells it is proposed to use the main flue as a common combustion chamber. It is claimed that the main flue or combustion chamber temperature varies from 1650° to 2000° Fahr., the minimum temperature after clinkering being 1000° Fahr. The air pressure in the ashpit is from 6 in. to 7 in. of water, and a considerable quantity of dust, amounting to about 1 cubic yard in eight hours, has been carried over into the flue.

It has been pointed out that the charge of refuse may be varied within certain limits. In practice it is found that it is not satisfactory to handle smaller charges than 1 cubic yard for any considerable time, because the frequent charging thus necessary to keep up the capacity of the plant tends to make the charging operation burdensome. It may therefore be taken that the charge of 1 cubic yard, the depth of refuse on the grate, the high-pressure draught, and the carrying over of dust, as well as the periodic lowering of the temperature immediately after charging, are inevitable. It is, however, but fair to point out that the temperature trouble would only be acute in the smaller installations.

The general arrangement of the experimental cell, showing the charging device and dust catcher, is illustrated in fig. 57.

Another form of charging device has been introduced by Stadtbauinspektor B. Berlit of Wiesbaden, in connection with the refuse destructor in that city. Here the destructor consists of six cells arranged in pairs, the total capacity being 100 tons daily. Above the cells a platform has been arranged, which is divided horizontally by a wall. The cart bodies containing the refuse are hoisted by means of a crane, and the contents are discharged on one side of the dividing wall. On the opposite side of the wall are the charging holes communicating with the grates. For each two charging holes a hinged shoot or tube is provided, which is so arranged that it may be swung over either of the two charging holes. This shoot leads through the dividing wall into the

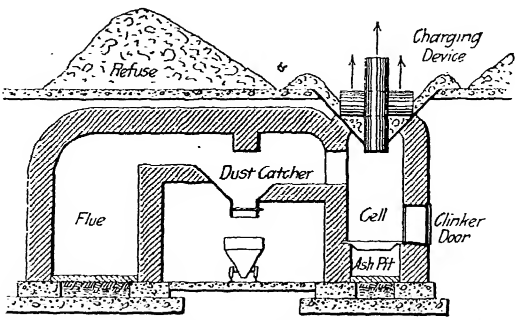

FIG. 57.—Experimental Cell at Hamburg.

refuse storage-room, at a height of about 7 ft. above the floor, the shoot being hinged a few feet out from the wall. Immediately underneath the shoot is a pit, arranged in the floor of the storage-room, in which is set a cylindrical charging can. The men in the storage-room rake the refuse, which is loosely heaped on the floor, into this can, which is then raised by means of a pulley and guides, the contents being discharged through the shoot into the cell.

The charging cans have a capacity of about 1 cubic yard, and the storage of the refuse, although somewhat objectionable, possesses the same advantage as at Hamburg, inasmuch as it is possible to mix or grade the contents into a charging can to suit the fire.

It will be observed that this charging device, in common with Herr Caspersohn's, does not do away with the necessity for a crane; the refuse must be lifted to the storage floor, while the open storage possesses all the disadvantage of the most unsatisfactory shovel-fed destructor.

At Wiesbaden each cell is charged about every forty minutes with

about 1 cubic yard of refuse. Forced draught is provided by means of motor-driven fans, a separate motor and fan being provided for each cell; the fan motors are equipped with a controlling device for regulating the speed—and accordingly the air pressure, to suit the condition of the fire.

Figs. 58 and 59 illustrate the installation at Wiesbaden prior to the modifications by Herr Berlit. The destructor, it will be observed, is of typical German design, and has been termed a "pit furnace." It is known as Müllverbrennungsofen system Dörr. Similar destructors have been erected at Beuthen O.S., Miscolz in Ungarn, Segefeld bei Spandau, and at Bologna, Italy. In connection with the Dörr destructors of recent design, a dust catcher has been introduced, somewhat similar in design to that already described in connection with Herr Caspersohn's experimental installation at Hamburg.

The following results were obtained with Berlin refuse burned in a Dörr Destructor:—

TABLE XVIII.

A.—Refuse collected in Rixdorf, Berlin, passed over a screen having a mesh of 3 m/m.

	No. 1.	No. 2 (with 5 per cent. of added fuel).
Date of test	Feb. 28, 1910	March 1, 1910
Refuse destroyed per cell per 24 hours, kilos	18,000	15,000–16,000
Average main flue temperature	650°–750° Cent.	840°–960° Cent.
Percentage of CO_2 in gases, average	13·15 per cent.	17 per cent.
Percentage of CO_2 in gases, highest	17·5 per cent.	...

B.—Refuse collected in Steglitz, Berlin, containing 52 per cent. of Brown coal (Lignite) briquette ash.
Refuse passed over a screen having a mesh of 3 m/m for No. 1 test only.

	No. 1.	No. 2.
Date of test	March 2, 1910	March 2, 1910
Refuse destroyed per cell per 24 hours, kilos	15,000–16,000	11,000
Average main flue temperature	650°–720° Cent.	350°–400° Cent.
Percentage of CO_2 in gases	10–13 per cent.	5–6 per cent.

The effect of the high percentage of Brown coal ash is very apparent in the figures of the second test, which seem to indicate that it is exceedingly difficult to satisfactorily deal with the refuse unscreened, unless the design of the destructor is modified.

In spite of all the attention which has been given by the German makers to the development of mechanical charging devices, there is no

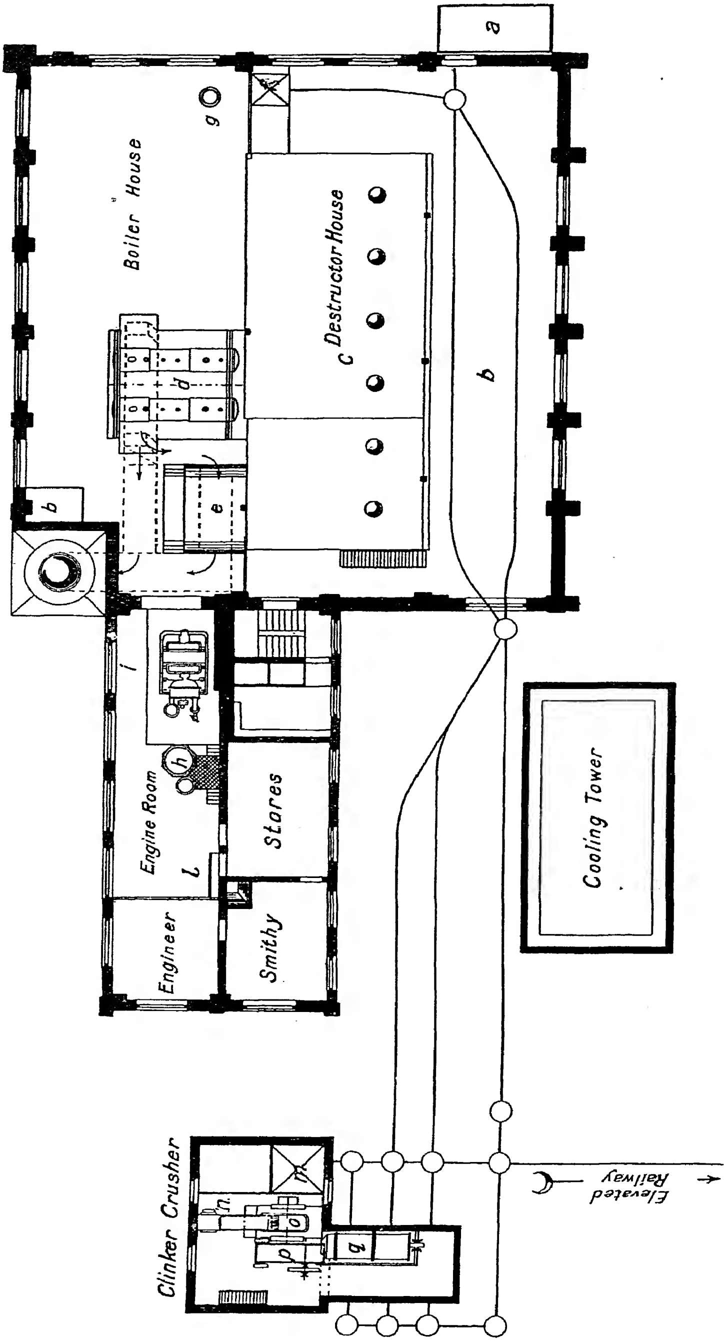

FIG. 58.—Dörr Destructor, Wiesbaden. Plan.

evidence that any striking progress has been made in comparison with the best British practice. The following figures are of interest as showing the variation in the weight of refuse handled per man per hour at Hamburg, Kiel, and Wiesbaden.

	Number of Men per Shift.	Tons Destroyed Daily.	Tons per Man, Hour.
Hamburg . . .	2	60	1·25
Kiel	8	125	·65
Wiesbaden . .	5	110	·90

While it is evident that in actual labour cost the Hamburg installation possesses a distinct advantage over the installations at Kiel and Wiesbaden, it is of vital importance to remember that the weight of refuse

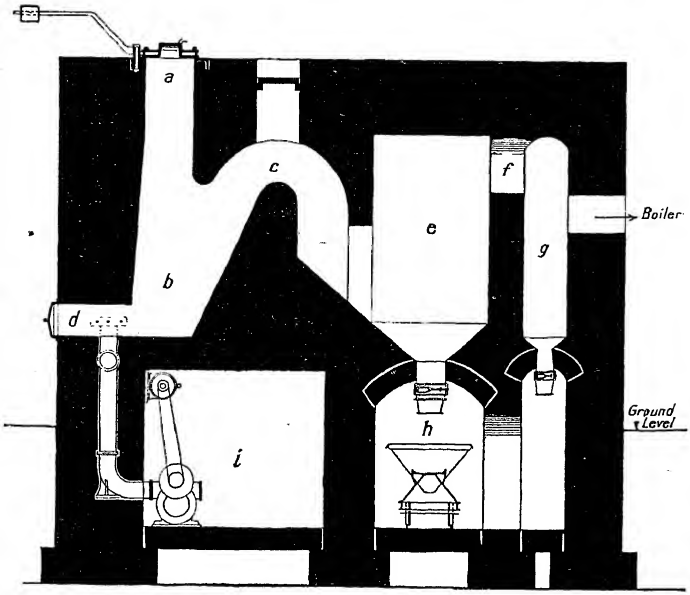

FIG. 59.—Dörr Destructor, Wiesbaden. Cross-sectional view through cell.

handled per man per hour, and accordingly the labour cost per ton of refuse destroyed, while being a very serious factor, is one which must be disregarded unless it can be shown that the cremation process is perfectly satisfactory. That there are serious objections to the typical German designs from a combustion point of view is beyond all question. Thick fires on such a limited grate area with very heavy air pressures do not present ideal conditions for combustion, while the dust trouble

is notorious; and in spite of the fact that German engineers have had the advantage of twenty years of recorded experience in Great Britain, they seem to ignore those points which long practical experience have proved to be of fundamental importance.

In British practice, the properly designed and arranged combustion chamber has given results which were never obtained in those days when the main flue was *supposed* to be the combustion chamber; and if a combustion chamber is of vital importance with the British type of destructor, which cannot be disputed, then its omission under such combustion conditions as obtain when burning refuse in a destructor of German design is a fatal blunder.

That the dust trouble with destructors of German design is very serious is proved by the abnormal measures adopted for the interception of the dust herein described. That these measures do not entirely overcome the trouble is evident. An ashpit pressure of from 7 in. to 12 in. of water will, under certain conditions, carry a considerable distance; and any serious resistance offered in the form of a dust catcher can only have the effect of aggravating the dust trouble beyond the point of interception, inasmuch as throttling at the dust catcher involves the provision of additional chimney capacity, and such dust as is not trapped at the dust catcher is the more likely to be emitted from the chimney.

It is claimed that in the working out of the German designs a greater scientific application has been brought to bear upon the various problems involved; this the author does not admit. The real value of scientific application and applied theory must be determined by their successful reproduction in practice.

In comparison with the best British practice, German practice is shown to be inefficient;[1] while developing accessories for the reduction

[1] This opinion appears to be confirmed by Herr Etienne de Fodor of Buda-Pest, in his recently published work in the German language, *Refuse Destruction*, by Etienne de Fodor (Buda-Pest, Julius Benkö), M. 5.

The latest comparative data available concerning British and German Continental installations are as follows; in each case the electrical output covers one year:—

Zurich (British).—180,347 kw. hours: 130,751 kw. hours used at works; 49,596 kw. hours by shops.

Frederiksberg (British) (Copenhagen).—496,187 kw. hours: 193,885 kw. hours used at works; 120,869 kw. hours by the Municipal Hospital; 2919 kw. hours for pumping water; and 125,514 kw. hours for private lighting. (The greater part of the steam generated is utilised for heating, cooking, washing, disinfecting, etc., in the large Municipal Hospital adjacent to the works.)

Frankfort (German).—2,290,143 kw. hours: 377,039 kw. hours used at works; 984,316 kw. hours for municipal lighting; and 927,788 kw. hours at the water works.

Barmen (German).—1,400,000 kw. hours: 300,000 kw. hours used at works; the balance for municipal purposes.

Brünn (German).—809,062 kw. hours: 138,615 kw. hours used at works; the balance for municipal purposes.

of labour, insufficient attention has been devoted to the primary essentials. In the practical application of the principles of combustion, the German types, as at present designed, cannot be regarded as satisfactory.

RUSSIA.

In all probability, the refuse of cities and towns in Northern Russia is among the most difficult to burn of any European refuse. Only those who have seen something of the refuse of St Petersburg, as collected during the winter, can appreciate the problem which it presents to the combustion engineer.

The irregularity of the collection, long exposure to the weather, and the presence of snow and ice during the winter months, make the problem of burning an exceedingly difficult one.

The author has seen refuse delivered at the destructor at the Narva boundary in St Petersburg during the month of December which, owing to prolonged exposure and decomposition, can only be described as a foul-smelling, black slime, probably containing nearly 80 per cent. of moisture.

While in England and many other countries the winter refuse is of much better quality than the summer refuse, in Northern Russia the conditions are reversed, the summer refuse being much superior to that collected in the winter.

The first destructor erected in Russia was at Czarskoe Selo, some 20 miles from St Petersburg, where H.M. the Czar occasionally resides. This installation, which is of the Horsfall top-fed type, was erected in 1906, and consists of two cells, arranged back to back, with two boilers of the Lancashire type. Forced draught is provided by a motor-driven fan.

When the author inspected this installation in December 1909 an average of 2500 poods, say 41 tons, of refuse were being destroyed daily, the refuse then being dry and apparently of much higher calorific value than the St Petersburg refuse, which may to some extent be accounted for by the well-organised and regular collection of refuse.

The building is well designed, lofty, and spacious, and the works generally would appear to have been designed and carried out regardless of expense.

Table XIX. is an analysis of the refuse of Czarskoe Selo, and as the components are given in considerable detail the table is of much interest.

TABLE XIX.

			Fresh Refuse (including Moisture).						Dried Refuse.*	
			Autumn.		Spring and Summer.		Average.		Average.	
			From	to	From	To	Autumn.	Spring and Summer.	Autumn.	Spring and Summer.
Combustible parts.	(1)	Remains of vegetables and animals, *i.e.* various refuse from kitchens, vegetable remains:—fruit, meat, bread, dough, flour, various leaves, etc.	12·49	448·05	11·44	155·00	150·43	121·39	24·63	27·67
	(2)	Grass and tree leaves . . .	3·36	625·09	...	...	130·10	...	99·32	...
	(3)	Bits of trees, matches, boxes, chips, bark, cork, twigs.	6·24	147·29	5·57	237·08	37·50	79·84	62·91	84·94
	(4)	Remains of charcoal (mostly wood charcoal)	0·66	56·28	1·32	36·72	9·87	5·74	10·72	5·40
	(5)	Remains of leather, rubber (straps, boots, etc.)	0·39	12·95	0·79	38·06	0·79	6·04	1·03	5·72
	(6)	Various rags, clippings of various fabrics, rags for cleaning, felt, old clothes, etc.	2·55	42·00	1·36	114·13	1·46	15·66	19·59	16·84
	(7)	Bast, string, remains of mat bags, mops, etc.	0·56	105·88	1·42	145·37	12·50	36·31	12·83	37·58
	(8)	Straw and hay packing, sweepings, etc.	0·15	160·76	0·22	293·63	26·40	107·55	10·58	116·48
	(9)	Various paper, cigarette ends, packing paper, writing paper	11·26	87·75	2·39	241·61	37·50	55·38	51·85	55·34
	(10)	Horse dung (mostly sweepings from yards and streets)	23·07	640·60	34·55	356·96	178·63	61·13	200·48	45·18
Parts by comb.	(11)	Bones, from fish, meat, etc. . .	2·45	30·09	0·9	89·24	10·67	14·25	18·69	15·08
	(12)	Egg-shells	0·37	10·73	1·42	14·42	4·33	2·66	7·40	3·32
Total non-comb.	(13)	Glass, stone, remains of broken dishes, tiles, etc.	2·3	174·8	2·76	214·43	40·92	59·75	78·97	82·32
	(14)	Metals, iron, lead, tins, etc. . .	0·25	30·01	0·91	76·44	5·69	15·78	11·07	21·74
Mixed parts.	(15)	Siftings—fine rubbish sieved, composed of fine sand; ash splinters, and fragments of the ingredients of refuse	54·88	527·51	100·19	737·89	142·65	233·31	227·48	300·00
	(16)	Refuse not sieved, sand, clay, sawdust, and fragments of above.	21·11	532·39	28·44	559·08	210·56	185·21	162·45	182·49
					Total .		1000·00	1000·00	1000·00	1000·00

* The refuse was dried at a continual temperature of from 100-110° Cent. to the usual weight.

RESUMÉ.

Season.	Water.	Combustible Parts.	Non-Combustible Parts.	Partially Combustible Parts.	Total.
Autumn fresh	48·62	23·86	4·92	22·60	100·00
Spring and Summer fresh .	27·41	28·68	7·55	36·36	100·00
On an average	38·01	26·27	6·24	29·48	100·00

The moisture varies from 10·56 per cent. to 56·7 per cent. The specific gravity of the refuse varies from 0·54 to 0·71, an average of 0·625.

Following the erection of the plant at Czarskoe Selo in 1906 the (Narva) destructor, St Petersburg, was erected. This plant consists of eight cells of the Horsfall tub-fed type, with one water-tube boiler. Forced draught is supplied by means of motor-driven fans. The cells are not provided with drying hearths, and the winter refuse is undoubtedly of such a difficult nature, and contains so much moisture, that the charges, which average about 3600 pounds, are much too heavy. The average evaporative value of the refuse may be taken as not more than ·4 pounds of water per pound of refuse, but this figure might be improved upon if the collection were regular, and the material burned under rational conditions. A test of the Horsfall plant in the month of May gave the following result:—

Duration of test	24 hours.
Total weight of refuse destroyed in eight cells	157 tons.
„ water evaporated	96,000 pounds.
Average main flue temperature . . .	870° Cent.

Cell No.	Consumption.	Temperature.	Blast Pressure.
1.	1123 poods* = 17·8 tons	790° Cent.	72 mm.
2.	1388 „ = 22·4 „	820° „	46·5 „
3.	1410 „ = 22·8 „	1012° „	40·5 „
4.	1205 „ = 19·4 „	967° „	46 „
5.	948 „ = 15·3 „	924° „	37 „
6.	1173 „ = 19 „	998° „	50 „
7.	1136 „ = 18·3 „	1010° „	44 „
8.	1146 „ = 18·5 „	970° „	58 „

* 1 pood = 36·2 pounds. 61·8 poods = 1 ton.

At the present time a second destructor is being erected by Messrs Heenan & Froude, Ltd., which will have a capacity of about 150 tons daily; but having in mind that about 700 tons of refuse daily have to be disposed of in St Petersburg, further installations will be required.

For a long time past the bulk of the refuse, in addition to a considerable quantity of fæcal matter, has been tipped outside the city at Gluchouzerskaya, and this tip, if not already closed, cannot be used much longer

In 1908 a cell Horsfall tub-fed destructor was erected at Warsaw.

The only other destructors of British design operating in Russia are at Odessa, where three small Horsfall front-fed destructors, each having 15 sq. ft. of grate area, have been erected.

Fig. 60 is a view of the cells from the clinkering floor of the Narva (St Petersburg) destructor, while fig. 61 is a view of one of the two destructor cells at Czarskoe Selo.

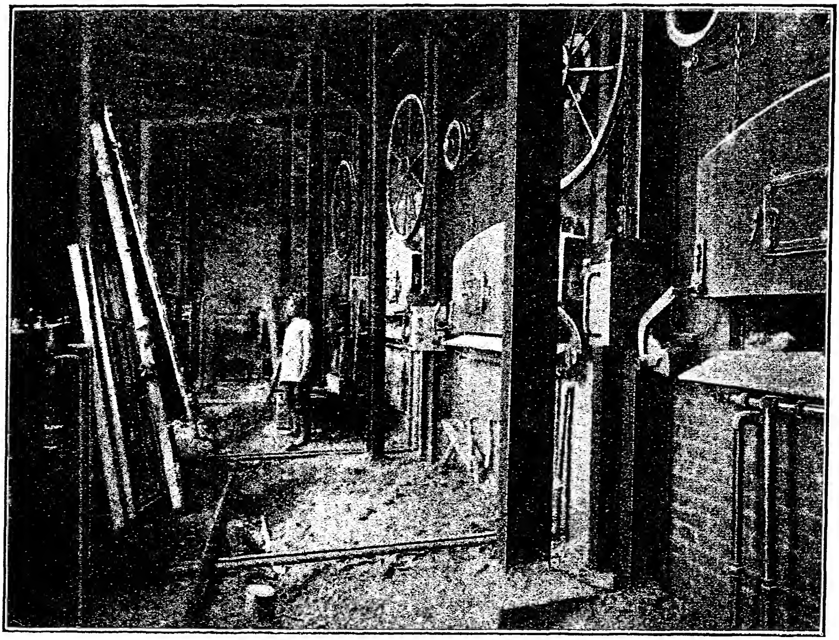

Fig. 60.—St Petersburg (Narva) Destructor in course of erection.

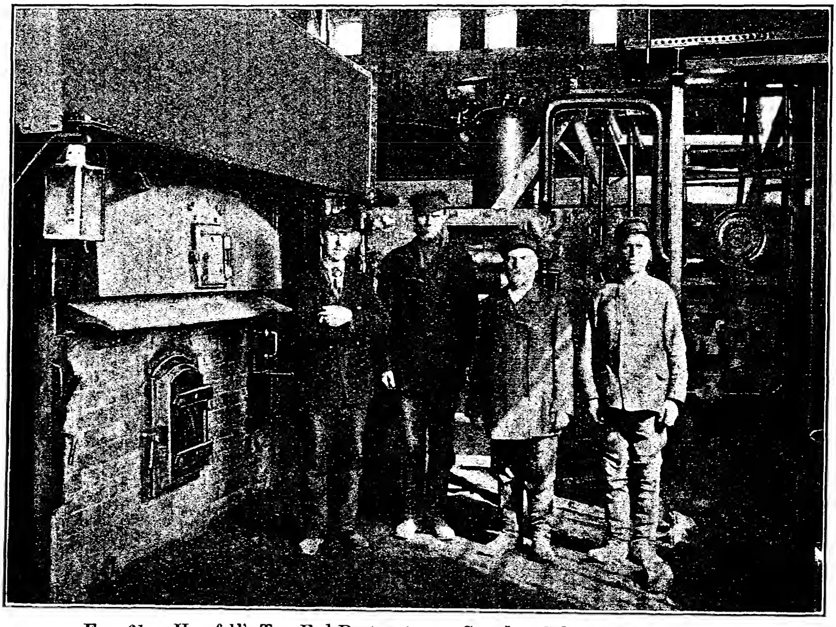

Fig. 61.—Horsfall's Top-Fed Destructor at Czarskoe Selo. Clinkering floor.

AUSTRALASIA.

Having in mind the comparatively small population of Australia and New Zealand, much progress has been made in the final and sanitary disposal of refuse, as will be seen from the following list of destructor installations:—

Adelaide, South Australia.
Leichardt, New South Wales.
Lithgow, New South Wales.
Balmain, New South Wales.
Melbourne, Victoria.
Perth, Western Australia.
Prahran, Victoria.
Sydney, New South Wales.
Toowoomba, Queensland.
Auckland, New Zealand.
Christchurch, New Zealand.
Wellington, New Zealand.

The earliest installations in Australasia date back to 1891, when a small plant of local design known as the Cracknell destructor was erected in Melbourne. In the following year a similar plant was erected at Fitzroy (Melbourne), followed by a 12-cell Fryer top-fed destructor at South Melbourne, and a 6-cell destructor of the same make and type at Wellington, New Zealand. At North Sydney, in 1892, a small destructor of local design known as the Pinhoe was tried, since which time every installation in the Antipodes has been of English make.

TABLE XX.—ANALYSES OF REFUSE OF MELBOURNE, PRAHRAN, AND FOUR OTHER ADJACENT TOWNSHIPS, COMPARED WITH THE REFUSE OF NORTH SYDNEY.

	Melbourne.	Prahran.	Hawthorn.	Kew.	Collingwood.	Richmond.	North Sydney.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Screenings, sand, or fine dust	42·81	26·23	...	...	...	...	40·16
Vegetable matter	13·28	16·34	56·7	54·5	19·00	7·0	26·98
Clinker, stones, etc.	1·32	...	...	...	...	...	1·48
Paper	7·36	6·52	3·65	4·6	5·0	...	5·0
Straw or fibre	1·63	...	...	...	2·0	...	...
Broken glass and bottles	1·44	1·97	·91	2·0	6·0	1	1·47
Old tins	1·11	1·70	4·32	2·5	7·0	3·0	2·0
Crockery	·56	...	...	...	...	...	...
Bones	1·03	1·23	·82	1·0	1·0	...	1·20
Rags	1·68	2·23	1·53	2·4	7·0	3·0	1·82
Iron	·33	·11	·016	...	...	...	·35
Cinders, coke	26·55	43·08	...	...	...	...	19·54
Wood	·90	...	...	...	...	...	...
Old boots	...	·50	...	...	...	...	...
Other metal	...	·09	...	...	...	...	...
Ashes and fine dust	...	...	31·92	33	53·00	86·0	...
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Table XX., p. 165, shows the composition of refuse in Melbourne, Prahran, and four other adjoining townships, compared with the refuse of North Sydney. While to some extent the composition of the refuse has changed since these analyses were made, from the combustion point of view the character of the refuse has not materially improved.

One point of considerable interest in connection with the various destructors erected in Australia during the past few years has been the outstanding superiority and successful operation of destructors of the shovel-fed type; the first of which, a front-fed destructor of the Meldrum type, was erected at Annandale and Leichardt, N.S.W., in 1902. The results obtained here, satisfactory as they are, have been improved upon at Prahran, Adelaide, and Wellington, N.Z. In Sydney, where two top-fed destructors had been erected, so convinced were the authorities as to the advantages of shovel-feeding with Australian refuse that two years since, when inviting tenders for a destructor to deal with 100 tons of refuse daily, a shovel-fed type of destructor was specified. A similar course was also adopted by the city of Adelaide.

TABLE XXI.—BRITISH DESTRUCTORS IN AUSTRALASIA.

	Maker.	Type.	Number of Cells.	Boilers.	Power used for
Adelaide S.A.	Heenan	Back-fed	6	2 Babcock	Works and electrical purposes.
Leichardt, N.S.W. .	Meldrum	Front-fed	2	1 Cornish	...
Lithgow, ,, .	,,	,, ,,	2	...	...
Melbourne, Vic.	Horsfall	Tub- ,,	6	3 Babcock	Electrical purposes.
Perth, W.A. . . .	,,	Back- ,,	3	1 ,,	...
Balmain, N.S.W. . .	Local	Top- ,,	2	1 ,,	Electrical purposes.
Prahran, Vic.	Meldrum	Front- ,,	5	2 ,,	,,
Sydney, N.S.W. . .	1 Warner	Top- ,,	6	1 multitubular	...
,, ,, . .	2 own design	,, ,,	8	...	...
,, ,, . .	3 Hughes & Stirling	Front- ,,	8	2 Babcock	...
Toowoomba, Q. . .	Beaman & Deas	Top- ,,	2	1 ,,	...
Auckland, N.Z.	Meldrum	,, ,,	3	1 ,,	Electrical purposes.
Christchurch, N.Z. .	Beaman & Deas	,, ,,	4	2 ,,	,,
Wellington . . .	Heenan	Back- ,,	9	3 ,,	Sewage works.

Some details of the British destructors now operating in Australasia are given in Table XXI. Having in mind that the earlier installations

have received much publicity, it is proposed to briefly describe the later and more important installations only. The latest installation, which is now rapidly approaching completion, is at Sydney, where Messrs Hughes & Stirling are erecting an improved "Sterling" front-fed destructor, having a capacity of 100 tons daily,

The destructor comprises two units of 4 grates each, with special offal hearths and carcase cremation chambers complete, with lifting tackle. In connection with each unit is a Babcock & Wilcox boiler, a regenerator and fan-forced draught, with complete arrangements for positive ventilation of the buildings.

The Adelaide destructor, erected by Messrs Heenan & Froude, Ltd., in 1910, is of the back-fed type, and consists of two 3-grate units with combustion chambers, Babcock & Wilcox boilers, regenerators, and motor-driven forced-draught fans. For the treatment and utilisation of the clinker a crushing and screening plant has been installed, as also a complete clinker flag-making plant; while for the compression of the tins—of which an abnormal quantity are always found in colonial refuse —a tin baling press has been installed.

For the utilisation of the steam, a Bellis & Morcom engine of 180 H.P. direct-coupled to a 120-kw. generator has been provided. At present the current is used for the motor-driven fans, the clinker, crushing, screening, and flag-making plant, and the tin baling press. While steam is supplied for a Washington Lyon disinfector, surplus current is sold to the Electric Lighting and Traction Company.

The destructor works are located on corporation property in Halifax and Gilles Street, the main building or destructor house being a reconstructed factory building which was originally five stories in height. Instead of providing an inclined approach roadway, which was difficult if not impracticable in connection with this site, the refuse is delivered at ground-level, the vehicles discharging the same into skips arranged in pits. The skips are raised and transported by means of an electric crane, and the contents are discharged into the storage hoppers or bunkers opposite to the back charging doors.

The destructor at Melbourne, erected in 1909, is of the Horsfall tub-fed type, and consists of six cells, and three water-tube boilers arranged in three units. The destructor works adjoin the electricity works at the corner of Spencer and Lonsdale Streets: the main bay of the destructor building is 134 ft. long × 37 ft. wide × 45 ft. high, the boiler-house being 84 ft. long × 20 ft. wide × 23 ft. high; the estimated cost of the buildings was £6350.

The schedule of cost of the destructor and accessories was as follows:—

	£	s.	d.
Six destructor cells with forced draught apparatus and firing tools	6,685	0	0
Three boilers with fittings and accessories, superheaters and brickwork settings	3,630	0	0
Flues, with dampers, cleaning doors and beast cremator	1,804	0	0
Centrifugal dust catcher, ironwork only	107	0	0
Feed pumps, tanks, injectors, and pipework	881	0	0
Six fans and motors	507	0	0
One Green's economiser, 128 pipes, with scraper gear and motor	706	0	0
One clinker elevator, crusher, motor, etc., and screen	734	0	0
One three-motor overhead travelling crane	507	0	0
Fifty refuse containers, pit and hopper	1,398	0	0
One exhaust feed-water heater	220	0	0
One CO_2 apparatus	5	0	0
Clinker railway	386	0	0
	17,570	0	0

The steam is to be fully utilised in the adjoining electricity works.

One of the most successful British destructors in the Antipodes is that of Prahran (Melbourne), which has been in operation since November 1907, and is of the Meldrum front-fed type, consisting of one 3-grate unit and one 2-grate unit, each unit having a combustion chamber, offal hearth, regenerator, Babcock & Wilcox boiler, and steam-jet blower forced draught.

Having demonstrated as the result of exhaustive tests that a considerable quantity of steam could be produced, it was decided to install generating plant with a view to selling the current for traction purposes; the results obtained have been exceedingly satisfactory.

The generating plant comprises a high-speed compound Allen engine of 185 H.P., coupled direct to a generator of the Synchronous inductive type, capable when fully loaded of giving an output of 125 kw. per hour. Current is generated at 400 to 440 volts, and passes from a switchboard direct to the mains of the Melbourne Electric Supply Company, the output being recorded on a Ferranti Watt meter.

During the year 1910[1] the weight of refuse destroyed was 7692 tons, while the number of Board of Trade units generated and sold was

[1] For the year 1911 the electrical output was 430,000 units, and the revenue therefrom £800.

343,010, or an average of 44·6 units per ton of refuse destroyed, exclusive of power used at the works. The revenue from the current sold was £698.

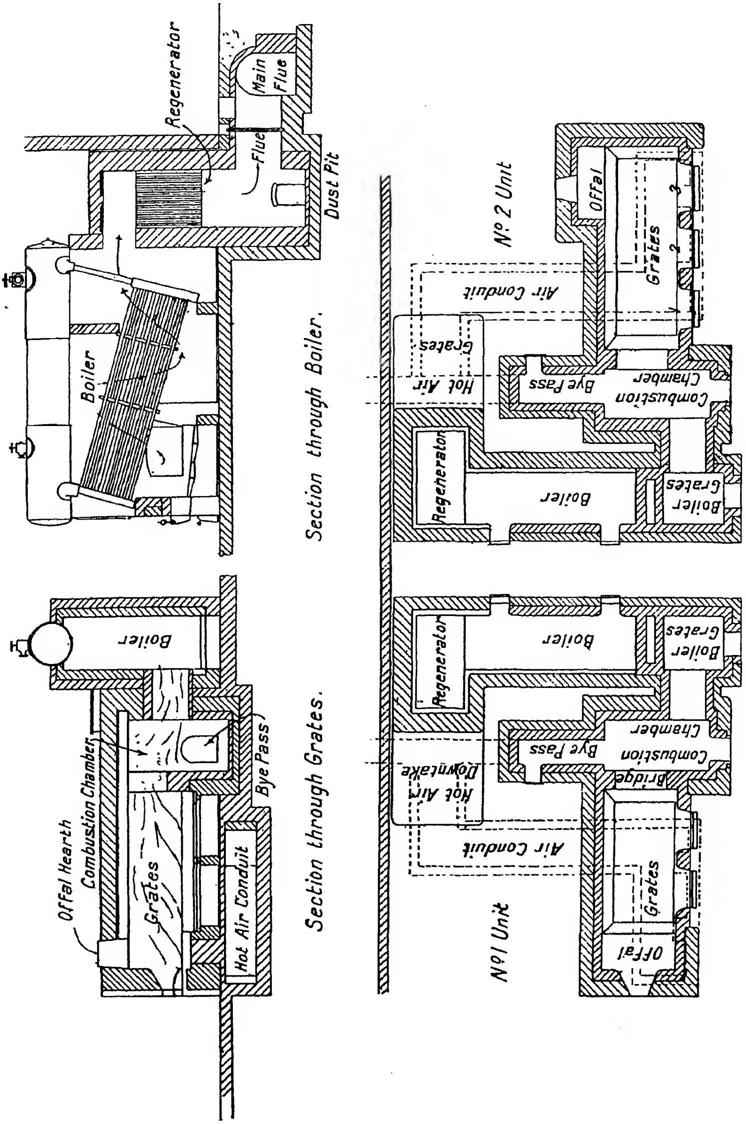

FIG. 62.—Meldrum's Front-Fed Destructor at Prahran (Melbourne). Plan and sections.

With the addition of superheaters to the boilers, there will doubtless be an increased efficiency, although even now the results obtained are the best recorded in connection with any combined destructor and

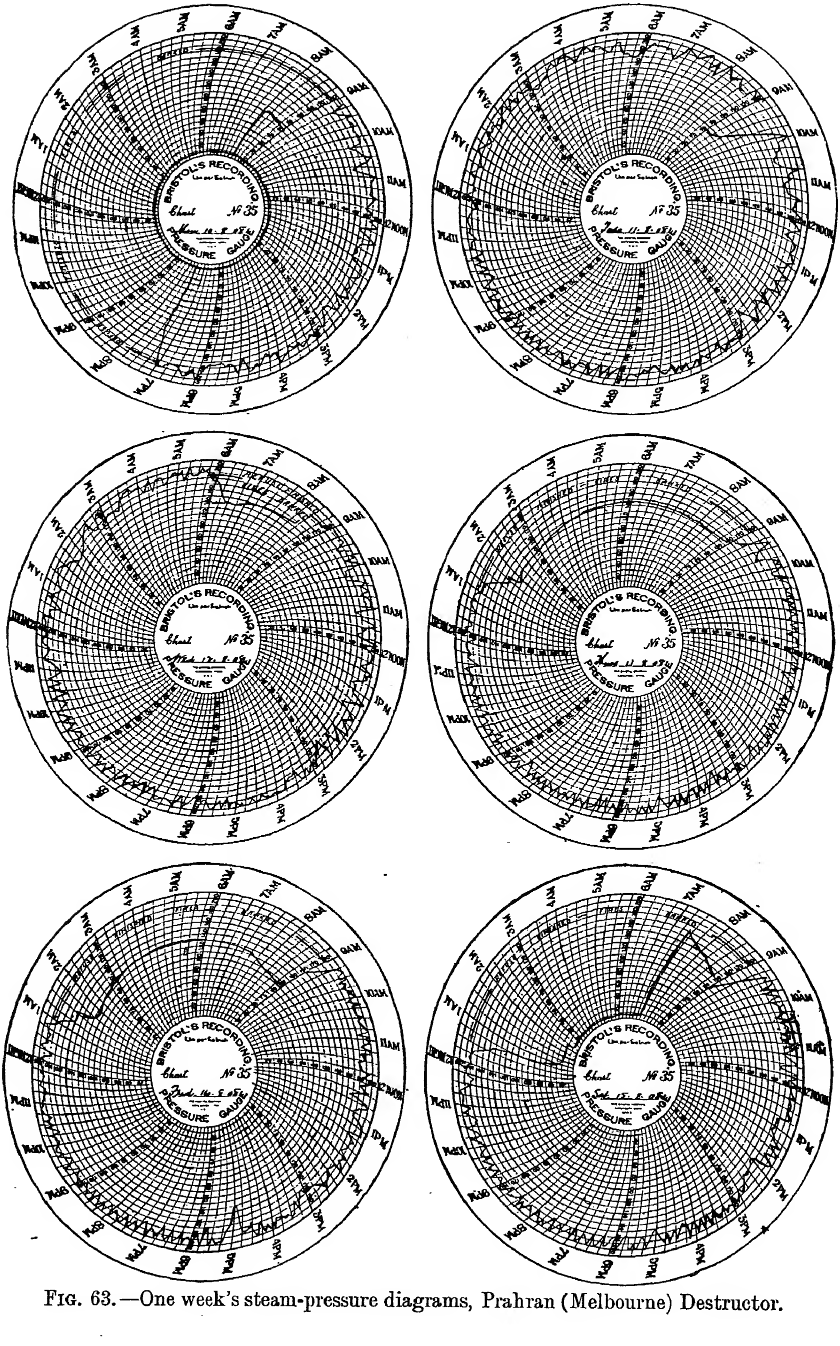

FIG. 63.—One week's steam-pressure diagrams, Prahran (Melbourne) Destructor.

electricity undertaking in the Colonies, and in advance of those obtained at most works of similar size in Great Britain.

During the year 1910, 1004 tons of clinker were crushed and graded, 434 tons being sold to builders and others, realising £112, the balance being used by the Council for a variety of purposes.

Having in mind the quality of the refuse, a very good clinker is produced: the following analysis of the same, made by Mr F. Dunn, is of interest for comparison with the appended analysis of Bradford (England) destructor clinker, by Mr F. W. Richardson, the city Analyst.

TABLE XXII.—PRAHRAN CLINKER.

	Per cent.
Silica (SiO)	58·11
* Alumina (AiO)	15·80
Oxide of iron calculated as (FeO)	7·07
Lime (CaO)	10·07
Magnesia (MgO)	1·93
Soda (NaO)	2·50
Sulphur	2·18
Potash (KO)	1·38
Carbon and undetermined	0·96
	100·00

* Containing some phosphoric acid.

BRADFORD CLINKER.

	Fine. Per cent.	Medium. Per cent.
Siliceous matter	61·08	67·10
Iron and alumina oxides	21·50	19·30
Carbonate of lime	7·80	6·
Magnesia	Traces	
Organic and volatile matters	4·12	1·80
Moisture	5·50	5·80

Much of the success of the Prahran undertaking is due to the thoroughness and well-directed energy of Mr W. Calder, the city Engineer of Prahran, whose aim has been not only to secure final and sanitary disposal without nuisance, but to make the undertaking self-supporting.

Plans and sections of the installation are shown in fig. 62, while fig. 63 illustrates the steam pressure charts taken during one week's ordinary work.

Fig. 64 is an external view of the Prahran destructor works. Fig. 65 illustrates the charging floor of the destructor, while fig. 66 is a view of one of the refuse collection vehicles designed by Mr Calder.

The following record for the month of August 1910, after the installation of superheaters in connection with the boilers, shows an average electrical output per ton of refuse destroyed of 52·6 Board of Trade units, and an average output per hour of 116·6 units.

TABLE XXIII.

Date Aug. '10.		Weight of Refuse Burned. T.	C.	Q.	L.	Time. H. M.	Units Sold.	Units per Hour.	Units per Ton.
M.	1	37	5	2	...	11 45	1,190	101·25	31·89
T.	2	36	1	1	...	14 30	1,510	104·13	41·88
W.	3	25	7	1	...	14 10	1,590	112·28	62·59
T.	4	26	15	...	21	13 25	1,560	116·25	58·31
F.	5	24	8	...	...	13 15	1,500	113·20	61·47
S.	6	16	5	...	...	7 55	880	111·25	54·15
M.	8	38	...	3	...	12 40	1,440	113·74	37·84
T.	9	28	11	...	...	14 20	1,620	113·04	56·73
W.	10	25	6	1	...	13 45	1,580	114·90	62·45
T.	11	24	5	...	...	12 20	1,420	115·16	58·55
F.	12	24	3	...	...	12	1,360	113·33	56·31
S.	13	16	9	3	...	7 50	860	109·83	52·12
M.	15	35	8	1	...	13 5	1,380	105·50	38·98
T.	16	31	1	...	...	14 10	1,590	112·28	51·20
W.	17	25	3	2	...	14 20	1,630	113·74	64·68
T.	18	24	11	...	...	12 15	1,330	108·56	54·17
F.	19	23	...	1	...	10 50	1,160	107·10	50·43
S.	20	16	...	2	...	7 30	850	113·33	52·95
M.	22	35	13	...	...	12 40	1,300	102·68	36·46
T.	23	28	17	2	...	14 15	1,590	111·57	55·01
W.	24	25	...	2	...	12 40	1,400	110·58	55·77
T.	25	23	4	2	...	11	1,180	107·27	50·75
F.	26	23	7	2	...	10 30	1,080	102·85	46·15
S.	27	23	2	...	...	9 40	800	82·81	34·63
M.	29	33	3	2	...	12 35	1,250	99·36	37·65
T.	30	27	2	3	..	13 20	1,550	116·27	57·09
W.	31	31	3	...	...	12 30	1,380	110·40	44·31
Totals		728	16	2	21	329 15	35,980	108·98 (Avg.)	49·36 (Avg.)

Units of electricity generated and sold through meter	35,980
" " " used on works	2,406
	38,386

Average 52·6 units per ton of refuse destroyed. Average 116·6 units per hour.

The destructor at Christchurch, N.Z., illustrated in figs. 67 and 68, was the first destructor to be combined with an electricity undertaking outside of Great Britain, and has been in operation since 1902.

This destructor, which is of the Beaman & Deas top-fed type, was

erected by Messrs Meldrum Bros., and comprises four cells and two Babcock & Wilcox boilers. The results obtained have been very satisfactory, the revenue both for light and power has increased rapidly, and

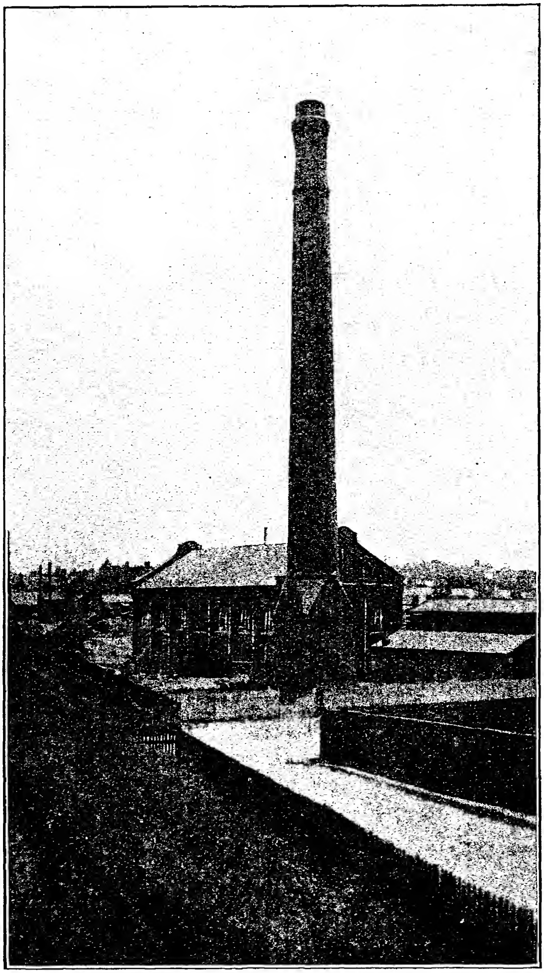

FIG. 64.—Prahran (Melbourne) Destructor Works. View of chimney and buildings.

the results generally have had the effect of stimulating much interest in combined undertakings. Fig. 69 illustrates the introduction of the carcase of a horse into the combustion chamber of the Beaman & Deas destructor at Toowoomba, Queensland. This destructor was erected for

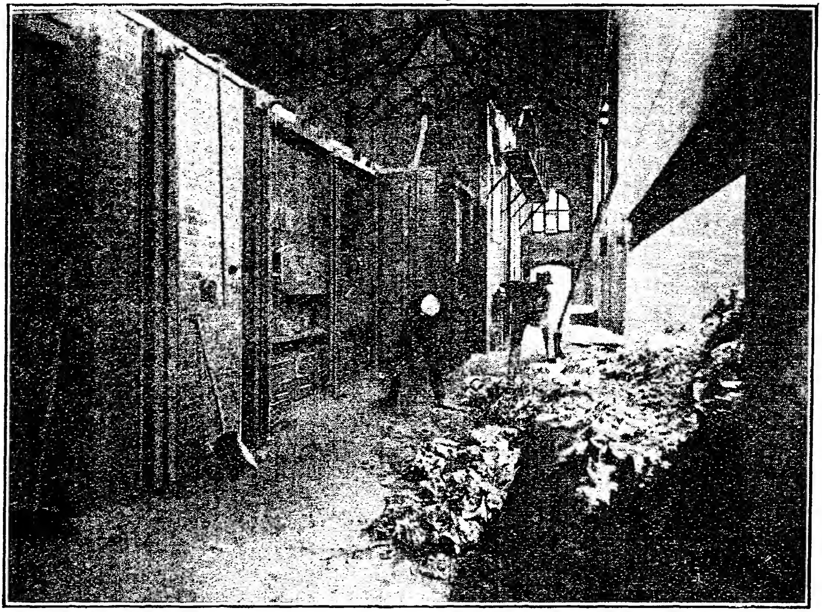

Fig. 65.—Prahran (Melbourne, Australia) Destructor. View of cells.

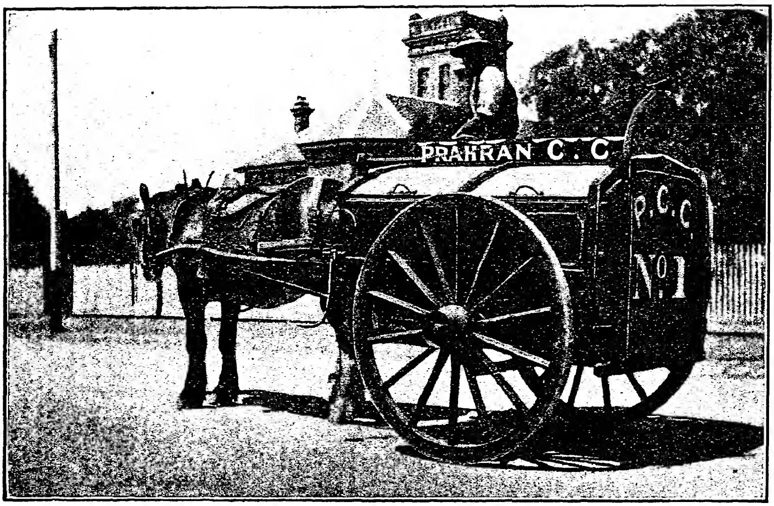

Fig. 66.—Prahran (Melbourne, Australia) Refuse Collection Van.

the disposal of excreta, and no special provision was made for the handling of occasional carcases.

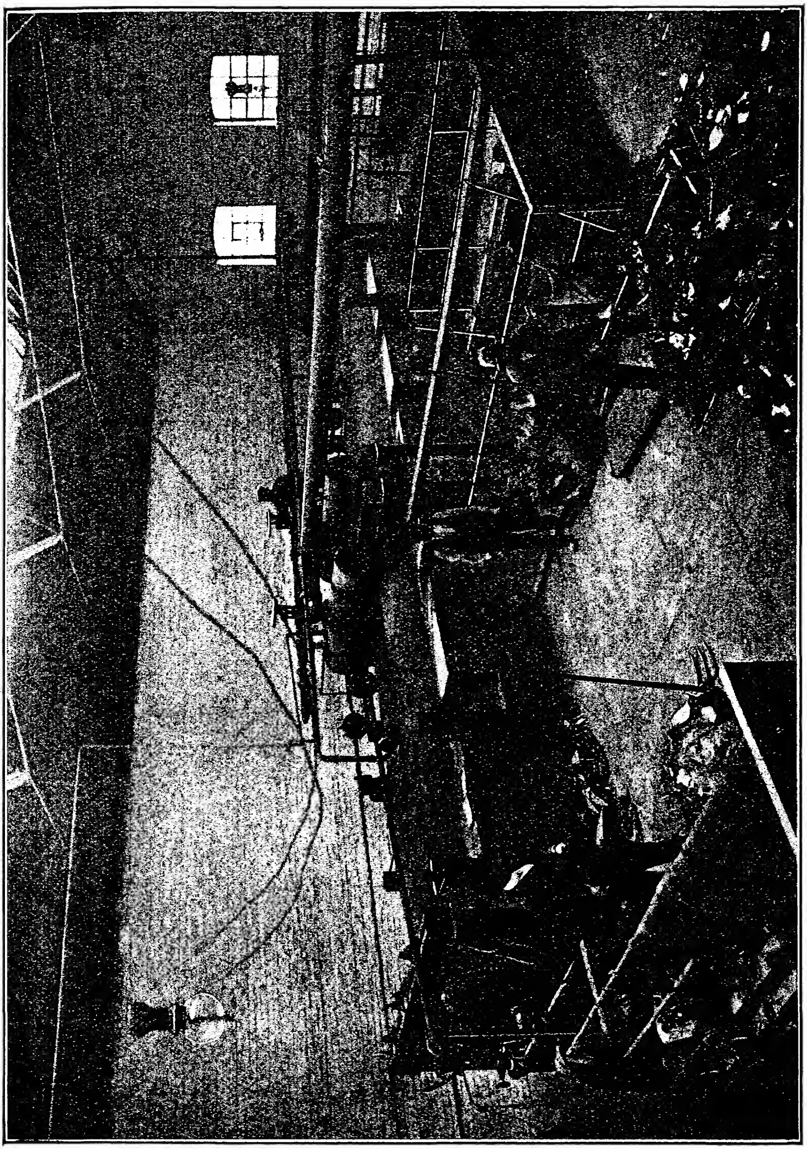

Fig. 67.—Christchurch (New Zealand) Destructor. View on top of cells.

As already observed in connection with the large destructor now approaching completion at Sydney, special lifting and transporting

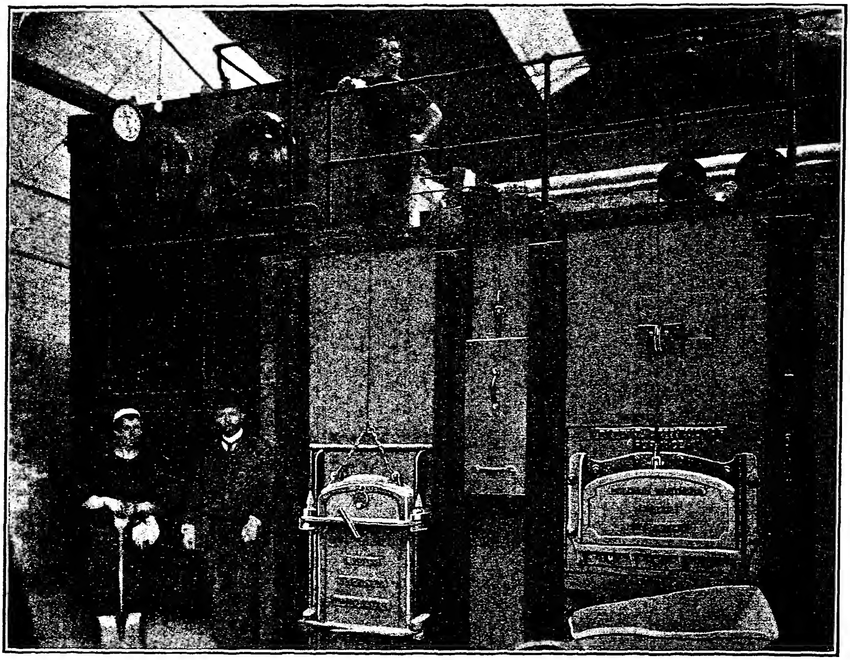

FIG. 68.—Christchurch (New Zealand) Destructor, showing boiler, combustion chamber, and clinkering door.

FIG. 69.—Toowoomba (Queensland) Destructor, introducing carcase into the combustion chamber.

tackle is provided, so that a large carcase may be dropped into the combustion chamber from above. A similar provision was made in connection with the destructor at Preston, which is illustrated in figs. 27 and 28, and such an arrangement is not only preferable but very desirable wherever any number of large carcases may have to be disposed of.

While it will be evident that most of the important cities of Australasia have already adopted refuse destructors, there is no doubt that within the next few years many of the smaller towns which are rapidly growing will decide upon final and sanitary disposal.

EGYPT.

At Cairo a Horsfall top-fed destructor of four cells was erected in 1903. At Alexandria, it has recently been decided to experiment with a combined destructor and refuse pulveriser works of French design.

AFRICA—SOUTH AND EAST.

Since 1900 the following municipalities have adopted British destructors:—

Bloemfontein.	East London.
Durban.	Johannesburg.
Kalk Bay (Muizenberg).	Mombasa.
Lorenzo Marques.	Zanzibar.
Pretoria.	

The destructors at Bloemfontein and Durban are of the Horsfall back-fed type, three and four cells respectively, and were both erected in 1904; the former installation being arranged to work in conjunction with the sewage works. In fig. 70 will be found a plan and sections of the Bloemfontein destructor.

At East London the destructor is of the Warner top-fed type and consists of four cells: this plant was erected in 1900.

The largest and most important destructors in South Africa are those at Johannesburg of the Meldrum top-fed type, of which there are two installations. No. 1 Burghersdorp destructor is illustrated in fig. 71, and originally comprised one four-grate top-fed destructor, with central combustion chamber, Babcock & Wilcox boiler and regenerator, together with a solder-recovery furnace, which is also shown in fig. 71. This installation, together with an exactly similar one, known as the Natal Spruit destructor, were erected during 1904–5, each being provided with a steel chimney 75 ft. in height, and having an internal diameter of 6 ft., lined throughout in firebrick.

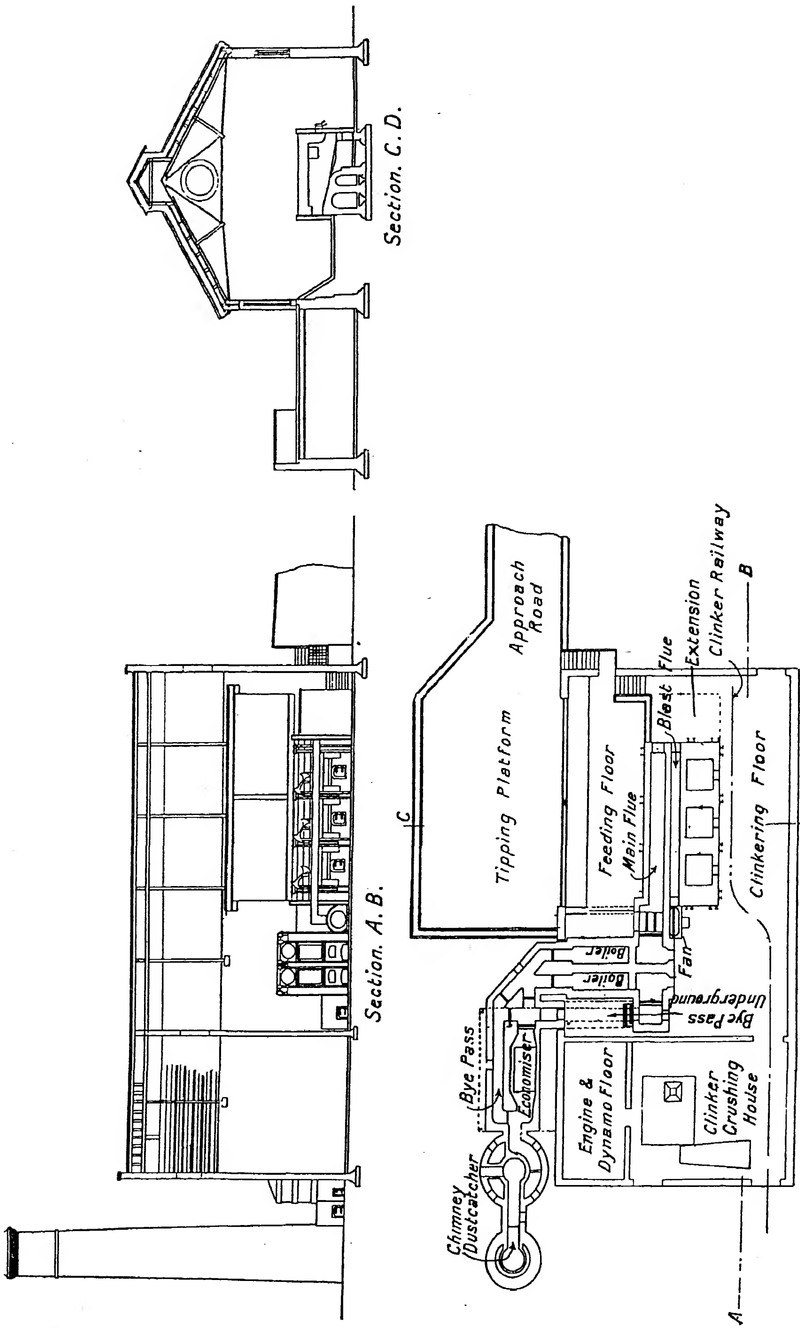

FIG. 70.—Horsfall's Back-Fed Destructor at Bloemfontein. Plan and sections.

In 1906 it was decided to duplicate the Burghersdorp destructor with a view to increasing the destroying capacity, and since this time about 180 tons daily have been destroyed at the two works.

At the Burghersdorp works, electric generating plant was installed to fully utilise the available steam, the energy being used for traction purposes, and this auxiliary supply has been found to be very satisfactory. While Stourbridge firebricks exclusively were used when the destructors were erected, it has been found that the Transvaal local fire-

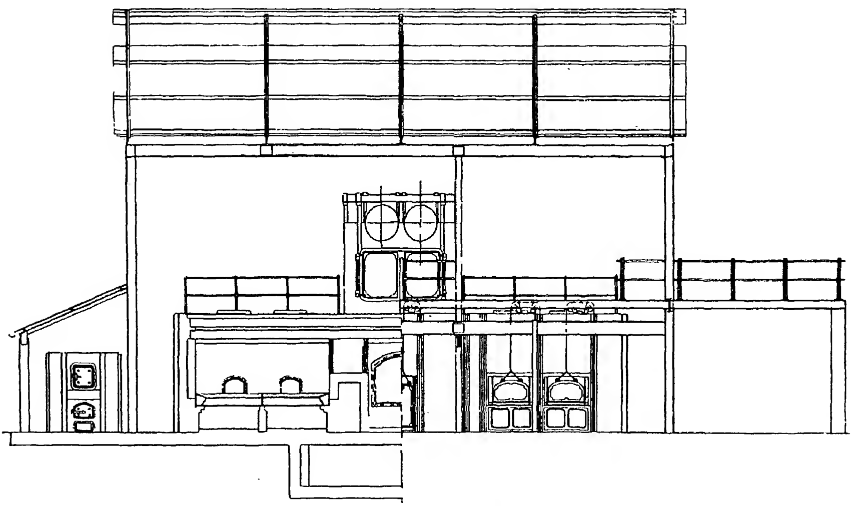

FIG. 71.—Meldrum's Top-Fed Destructor at Johannesburg (Burghersdorp). Part elevation and part section of one unit.

bricks are of very good quality and stand well; they have been used for all repairs.

At Kalk Bay (Muizenberg) a two-grate Meldrum front-fed destructor, with Babcock & Wilcox boiler and regenerator, was erected in 1906 in conjunction with a sewage pumping station.

The destructor at Lorenzo Marques is of the Horsfall back-fed type, 2 cells, and was erected in 1904.

The Pretoria destructor was erected in 1907, and is of the Meldrum top-fed type, in design and general arrangement being similar to those erected in Johannesburg.

The installations at Zanzibar and Mombasa, erected in 1909 and 1906 respectively, are of the Horsfall type, the former being a 2-cell back-fed plant, and the latter a single cell of the front-fed type.

THE FAR EAST.

Comparatively speaking, little has yet been done in Oriental countries in final and sanitary refuse disposal. The destructors in India are but few, while in China and Japan no progress has yet been made.

The very extensive use of refuse for manurial purposes both in China and Japan, and the facilities offered for thus disposing of garbage, frequently at a considerable distance from inhabited areas, tends to make the problem of disposal far less acute than is generally supposed.

It is scarcely necessary to observe that the refuse of the Orient is of very low calorific value. In the following Table XXIV. the component parts of Shanghai refuse are compared with the average refuse of London.

TABLE XXIV.—TABLE FROM REPORT OF THE SHANGHAI MUNICIPAL COUNCIL FOR YEAR ENDING DECEMBER 31, 1899 (MR CHARLES MAYNE, ENGINEER AND SURVEYOR).

Percentages * by Weight of the Component Parts of Shanghai Garbage for each Month of the Year, together with the Component Parts of Average London Garbage.

Component Parts.	Shanghai Garbage.												Average London Garbage.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
Bricks and broken roof tiles	3·497	2·590	1·928	2·684	1·961	2·702	2·260	1·703	2·680	2·860	1·481	1·491	..
Cinders and ashes	27·388	31·257	30·530	27·544	17·167	21·697	12·841	12·224	11·303	10·213	9·972	8·330	69·69
Fine dust	45·285	40·791	42·409	40·798	37·204	43·789	47·630	35·588	31·790	34·511	35·050	32·785	19·51
Vegetable, animal, and various organic matter	13·776	14·750	14·304	17·551	34·121	18·092	23·785	37·745	45 925	44·006	45·552	50·098	4·61
Wastepaper	·546	·564	·385	·419	·435	·569	·329	·220	·198	·242	·182	·212	4·28
Straw and fibrous material	8·102	8·694	9·251	9·667	8·094	11·822	11·973	9·380	7·283	7·100	6·749	5·916	3·22
Bottles unbroken	..	..	..	..	..	..	..	.	..	..	..	..	·96
Coal and coke	..	..	..	..	..	..	..	..	..	..	..	..	·84
Tins	·538	·433	·292	·257	·259	·282	·227	·216	·122	·238	·179	·223	·79
Crockery	·386	·455	·494	·373	·277	·369	·282	·245	·181	·253	·215	·276	·55
Bones	·058	·056	·047	·069	·088	·088	·062	·063	·048	·055	·063	·065	·48
Broken glass	·078	·085	·079	·082	·074	·103	·122	·115	·075	·096	·088	·069	·47
Rags	·182	·141	·122	·172	·161	·222	·727	·182	·169	·178	·179	·196	·39
Iron	·062	·063	·051	·058	·052	·083	·076	·089	·052	·058	·076	·076	·21
Wood	·152	·121	·108	·146	·128	·182	·186	·230	·174	·190	·224	·263	..
	100	100	100	100	100	100	100	100	100	100	100	100	100

Includes cabbage leaves, rinds of water melon and pumpkin, khobar, feathers, dead cats and dogs, putrid meat, old shoes, fish and fowl entrails, fish heads and bones, refuse from the manufacture of beancakes and Chinese sauce (soy), etc.

* The above figures were arrived at by taking a sample cartload of garbage at random every day throughout the year, and the figures tabulated are a fair average.

In the tropical countries the refuse is exceedingly low in calorific value, and in the rainy season the percentage of moisture is very heavy indeed.

Under such conditions the problem of disposal by fire without the use of any supplementary fuel is a very difficult one. The destructor, as ordinarily designed, for dealing with the average British refuse, is not at all likely to satisfactorily dispose of wet tropical refuse.

Needless to add, the drying hearth, which is now but rarely used in England, is of vital importance in tropical countries, but the provision of a drying hearth without some further effective means of rapidly drying the charge of refuse will not solve the difficulty. The author is of opinion that some means for directing an ample volume either of heated air or hot gases upon or through the material on the drying hearth offers the best solution of the difficulty; further, small charges of refuse must be insisted upon, even although it involves practically continuous charging.

STRAITS SETTLEMENTS.

Penang.—(Municipality of Georgetown.)—The destructor here is of the Heenan top-fed type, and consists of 4 cells, a combustion chamber, water-tube boiler and regenerator. Including the building, approach road and chimney, the total cost of the installation was £7427, 14s. 11d.

The guaranteed destroying capacity of the plant was from 40 to 50 tons of average Penang refuse per 24 hours, without the use of any supplementary fuel.

The following figures are extracted from a report, and serve to illustrate the severe conditions under which destructors are operated in tropical countries during the wet season:—

Date.	Loads burned.	Hours worked.	Rainfall registered for 24 Hours ending 9 a.m.
August 14, 1910 . .	88	20	...
,, 15, ,, . .	124	24	2·38 in.
,, 16, ,, . .	100	22	·61 ,,
,, 17, ,, . .	82	19	2·42 ,,
,, 18, ,, . .	98	22	1·26 ,,
	492	...	7·07 in.

The loads are estimated at 7·4 cwt. each, 492 loads therefore = 182 tons, or 36·4 tons per day and 9·1 tons per cell, which, having in mind the low calorific value of the refuse and its saturated condition, must be regarded as a very satisfactory result.

The operating charges of the destructor per month are as follows:—

Superintending engineer	$50.00
Superintendent	150.00
3 engine-drivers at $50 each	150.00
16 firemen at $15 each	240.00
13 coolies at $10 „	130.00
Coolies removing carcases	8.00
2 bullock carts daily removing clinker at $1.30 per cart per day	80·60
Lighting 2 Kitson lamps at $1.40 per night each	86.80
Sundry tools, material, fuel, etc., say	104.60
	$1000.00

Singapore.—A four-cell Horsfall back-fed destructor was erected here in 1906, followed by a Heenan top-fed destructor in 1909. At the present time a second installation of the Heenan top-fed type is in course of erection.

Calcutta.—In 1903 a destructor of the Baker type was erected, consisting of nine cells, each having a grate area of 50 sq. ft., with two Babcock & Wilcox boilers. The plant was arranged for working either with forced draught or induced draught, or both.

The guaranteed destroying capacity of the plant was 135 tons per twenty-four hours, which quantity was exceeded during the tests.

The boiler furnaces were arranged as cremators, some 30 to 40 maunds of coal per twenty-four hours being burned when the destructor was dealing with about 150 tons of refuse daily.

Madras.—The first destructor erected here was of the Warner top-fed type, comprising twelve cells. In 1902 a three-cell destructor of the Harrington type was erected. The Harrington destructor, known in India as the "Mofussil," was also tried in both Calcutta and Mandalay, British Burma. It was specially designed by Mr B. R. Harrington of Calcutta for the disposal of Indian refuse without the use of supplementary fuel, but does not appear to have been very successful.

Karachi.—A six-cell destructor of the Warner top-fed type is in use here.

Naini Tal.—In 1907 a single-cell Horsfall destructor of the front-fed type was erected here.

Colombo, Ceylon.—At the present time a four-cell Horsfall back-fed destructor, of the continuous grate-type, is in course of erection.

SOUTH AMERICA.

Pernambuco, Brazil.—A four-cell Horsfall destructor of the back-fed type was erected here in 1896. One multitubular boiler was installed for the forced-draught supply and works purposes.

Nine years later Messrs Manlove, Alliott & Co. erected a six-cell top-fed destructor with one water-tube boiler.

Para, Brazil.—In 1892 a Fryer destructor of the top-fed type was erected here, while in 1900 a Horsfall top-fed plant of four cells was erected.

Santos.—A Heenan destructor, having a capacity of 25 tons daily, has been erected here recently.

Buenos Ayres (Argentine).—An experimental plant was erected here by Messrs Baker, consisting of two cells and one Hornsby water-tube boiler. The refuse of Buenos Ayres contains from 40 per cent. to 60 per cent. of moisture; the proportion of cinder and ash is very low indeed; generally the refuse may be taken as typical of that produced in the Argentine and Brazil.

Manaos.—A Horsfall destructor is now in course of erection here.

Georgetown, Demerara.—A destructor of the Fryer top-fed type was erected here about fifteen years ago.

CHAPTER XII.

UNITED STATES AND CANADIAN PRACTICE.

SEVEN years ago, in an article contributed to *The Municipal Journal and Engineer* by the author, the opinion was expressed that, owing to the many failures of American crematories and incinerators, it was becoming increasingly evident that no real progress would be made in the United States until destructors of British types were adopted.

That this opinion was well founded has been conclusively demonstrated by the developments during the past five years. In spite of the extraordinary and impossible guarantees offered by the makers of American furnaces, and their hostile attitude and criticism, it has been shown that destructors of British types are capable of fulfilling the very severe conditions which have been formulated and imposed by those American engineers who have specialised in refuse-disposal work.

The problem of refuse disposal in the United States is unusually complex for various reasons, the principal of which it is worth while to briefly review.

Firstly, owing to the varying climatic conditions, the refuse differs very considerably in its composition. In the northern and eastern States the percentage of calorific material is high, while in the southern and western States the percentage of garbage is very high.

To a much greater extent probably than in any other country, local conditions affect the composition of the refuse. For instance, the use of natural gas in certain cities and towns has the effect of materially reducing the percentage of available ash and cinder. Again, in other localities, where wood is the staple fuel, there is an entire absence of that calorific residual which is so valuable in the burning of garbage.

While it is perfectly true that in other countries somewhat similar conditions obtain, the vital difference is that in all other countries where the percentage of calorific material is low, the same conditions

obtain to a large extent throughout the country, whereas in the United States the conditions vary widely.

Secondly, it must be clearly recognised that in American cities and towns refuse is more or less classified, and there are preferably separate collections of (1) garbage, (2) ashes, and (3) rubbish. Generally speaking, a single collection of mixed refuse, as in England, is not favoured, and a people of utilitarian ideas are not altogether satisfied that the most economical course is to destroy all three classes of refuse.

FIG. 72.—New York, a Rubbish Tip in summer.

The disposal of garbage by a reduction or utilisation process has many advocates, while ashes are favoured and are very extensively used for land filling, to which use there appears to be no objection. In so far as the rubbish is concerned, there is a general consensus of opinion that this should be burned, not because it is deemed harmful, but rather because it demands much space and is unsightly. Fig. 72 illustrates a New York rubbish dump in summer.

Thirdly, the problem is difficult because the past history and record of American furnaces is disastrous. Failures all over the Continent during a long period of years have convinced many that cremation is

impossible. The offensive smells in connection with many reduction works has done much to convince others that garbage cannot be treated by a reduction system without a very serious nuisance.

While it is true that the latest reduction works, as also the destructor installations of British types herein described and illustrated, are perfectly satisfactory, and while confidence is gradually being restored, it will take time, and a multiplication of the present successful installations, before the memory of nearly 150 failures can be obliterated.

The first British destructor was erected in Canada and put into service early in 1906 at Westmount (Montreal), and was of the Meldrum top-fed type. This installation was quickly followed by the erection of a Heenan back-fed destructor at Vancouver, B.C., and a Meldrum front-fed destructor at Seattle, Wash., which was the first British destructor erected in the United States.

Following exhaustive investigations in England by Mr J. T. Fetherston, Superintendent of Cleansing of the borough of Richmond, Staten Island, it was decided to erect a Heenan back-fed destructor at West New Brighton, Richmond borough, N.Y., which plant was put into operation early in 1908.

The successful work recorded in connection with the four installations already referred to quickly led to the provision of further British destructors. Acting upon the advice of Mr Rudolph Hering of New York, the city authorities of Milwaukee decided to erect a destructor having a daily capacity of 300 tons. Although the Milwaukee plant was only completed in April 1910, British destructors were decided upon for the cities of Buffalo, N.Y., and Montgomery, Ala.; it was further decided to duplicate the Westmount destructor; and during the present year the same course has been followed at Seattle and Buffalo, while contracts have also been placed for a second destructor for the borough of Richmond, Staten Island, N.Y., which plant will be known as the Clifton destructor, and two destructors for the city of San Francisco, Cal. Such is the British record in the United States and Canada during the past five years.

The original installation at Westmount (Montreal) has received much publicity; a brief description of the same will therefore suffice.

The destructor is of the Meldrum top-fed type, consisting of three grates, a total of 75 sq. ft., a combustion chamber, a Babcock & Wilcox water-tube boiler, having 2197 sq. ft. of heating surface and a regenerator. The steam is fully utilised in connection with the combined electricity works.

The buildings are in brickwork, and the chimney, which is of the Custodis type, is 150 ft. in height. The destructor site is an admir-

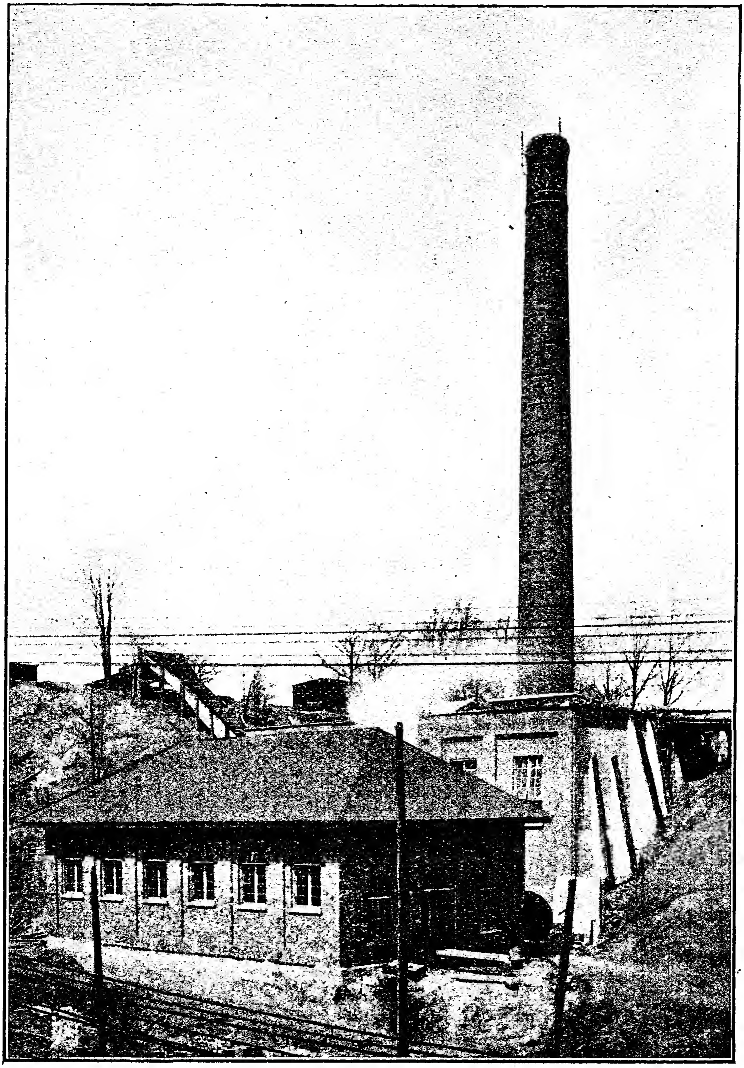

FIG. 73.—Westmount (Montreal) Destructor, view of buildings and chimney.

able one, inasmuch as the refuse is delivered to the storage hoppers without an inclined approach, while the depth available is such as to permit of the clinker being raked direct from the grates through

shoots in the clinkering floor to the storage and cooling chamber beneath.

Forced draught is provided by steam-jet blowers, and, as will be

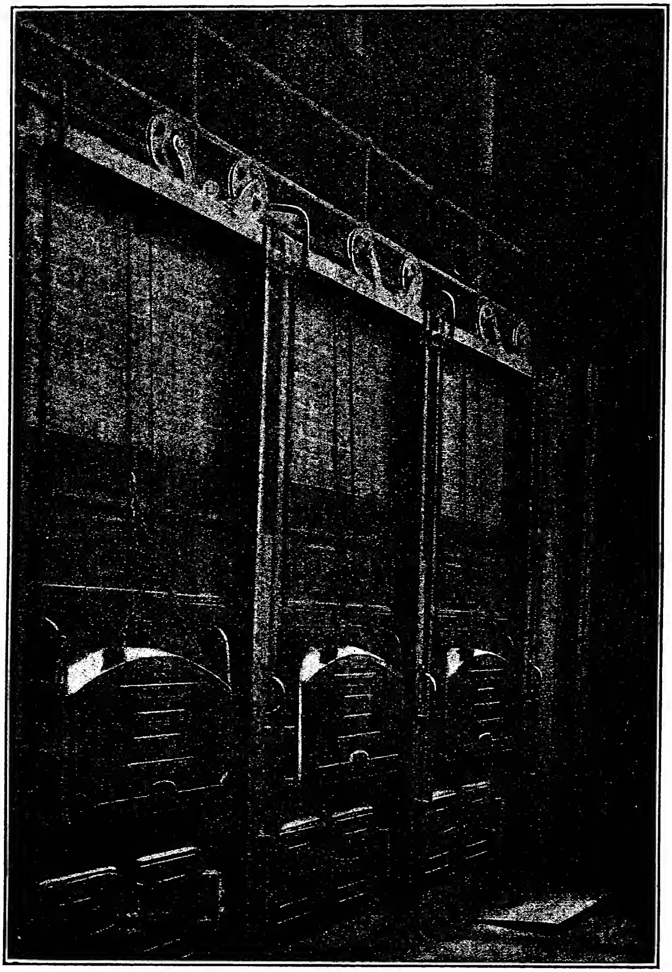

FIG. 74.—Meldrum's Top-Fed Destructor at Westmount (Montreal), view of cells at clinkering floor.

seen upon reference to the accompanying official test figures, exceedingly good results were obtained. Fig. 73 is an external view of the combined destructor and electricity works, while fig. 74 is a view of the cells at the clinkering floor.

TABLE XXV.

WESTMOUNT MUNICIPAL REFUSE DESTRUCTOR AND ELECTRIC PLANT.

Results of Test, May 3, 1906.

Duration of test	8 hrs. 32 mins.
Number of cells	3
Total grate area	75 sq. ft.
B. & W. boiler, heating surface	2,197 „

Refuse Consumed. Composition.

Garbage, manure, and leaves	15 per cent.
Anthracite ashes, unburnt coal, cinders, etc.	65 „
Iron, wood, bottles, tins, leather, etc.	5 „
Refuse, including paper, branches, old furniture, etc.	15 „
Total	100 „

Weights.

Unscreened ashes, refuse, rubbish, garbage, manure, etc.	38,090 lbs.
Tins, etc., not burned	540 „
Net amount consumed	37,555 „
Refuse consumed per hour	4,402 „
Refuse consumed per hour per sq. ft. of grate	58·7 „
Weight of clinker remaining after combustion	15,880 „
Percentage of clinker and ashes to refuse consumed	42·1 per cent.

Water Evaporation.

Total water evaporated	41,991 lbs.
Water evaporated per hour, actual	4,920 „
„ „ per hour, from and at 212° F.	5·970 „
„ „ per lb. of refuse, actual	1 12 „
„ „ per lb. of refuse, from and at 212° F.	1·36 „
Water evaporated per lb. of refuse, from and at 122° F. and per sq. ft. of total heating surface, per hour	2·72 „

Pressures and Temperatures.

Temperature of the outside air, average	55° F.
Barometric pressure, average	29·5 in.
Average steam pressure	123·5 lbs. sq. in.
„ pressure in ashpits	1·74 in.
„ vacuum at chimney base	9–16 „

Average temperature of combustion chamber (by Watkins heat recorders) over	1,994° F.
Highest temperature of combustion chamber (copper melted in 1¼ minutes, wrought iron also fused) over	2,318° F.
Lowest temperature in combustion chamber . .	1·742° „
Average temperature air entering regenerator .	75° „
„ „ air leaving regenerator .	206° „
„ „ gases entering regenerator .	427·5° „
„ „ gases leaving regenerator .	333·7° „
„ „ of feed water . . .	47° „

Gas Analyses.

Percentage of CO_2, average of six readings . .	10·9 per cent.
„ „ CO_2, highest reading . . .	13·6 „
„ „ CO_2, lowest reading (clinkering fires)	4·5 „

Times.

Time taken to clinker one grate	10½ mins.
Time between clinkerings	2 hrs. 48 mins.
Times each fire was clinkered	3

Remarks.—A delay of about three-quarters of an hour was caused by non-delivery of garbage in the early part of the afternoon, during which time no fresh charge was added to the fire. Had this not been the case, the total quantity of refuse could easily have been destroyed within eight hours, as the fires had to be held back somewhat on this account, and a somewhat better showing could have been made in the burning capacity of the destructor had sufficient garbage been delivered to force it to its utmost capacity.

The extension or duplicate plant at Westmount was put into service in March 1910, and is of the Heenan top-fed type, comprising three grates = 75 sq. ft., a combustion chamber, a Babcock & Willcox water-tube boiler, having a heating surface of 2197 sq. ft., with a superheater and a regenerator. Forced draught is provided by means of a 66-in. diameter centrifugal fan, direct coupled to a vertical high-speed enclosed engine.

The following test figures call for some little explanation. In connection with test No. 1, the refuse was considered to be of poor quality, containing a high percentage of very fine dust from anthracite ashes. It being agreed that the refuse fell short of the average quality which should have been provided in accordance with the terms of the guarantee this test was not taken as a guarantee test.

TABLE XXVI.

	Test No. 1.	Test No. 2.	Test No. 3.
Date	March 22, 1910.	March 29, 1910.	April 12, 1910.
Duration	$9\frac{1}{2}$ hours.	$6\frac{2}{3}$ hours.	$5\frac{3}{4}$ hours.
Details of Fuel.			
Mixed refuse, garbage, etc., delivered	10,575 lb. = 36·9%	15,790 lb. = 51 %	21,110 lb. = 69·92%
Mixed Ashes delivered.			
Combustible dust	18,085 lb. = 63·1%	15,590 lb. = 49 %	3,200 lb. = 10·61% 5,800 lb. = 19·47%
Total delivered	28,660 lb. = 100 %	31,380 lb. = 100 %	30,190 lb. = 100 %
Mixed refuse, garbage, etc., burnt	10,570 lb. = 36·9%	15,790 lb. = 51 %	21,110 lb. = 86·84%
Screened combustible ashes	None	None	3,200 lb. = 13·16%
Unscreened combustible ashes	18,085 lb. = 63·1%	15,590 lb. = 49 %	None
Total burnt	28,660 lb. = 100 %	31,380 lb = 100 %	24,310 lb. = 100 %
Total clinker	9,805 lb. = 34·4%	6,270 lb. = 20 %	7,025 lb. = 28·8 %
Total dust in furnace	3,000 lb. = 10·5%	1,000 lb. = 3·2%	
Ratio of clinker and dust to refuse, etc., delivered	12,805 lb. = 44·7%	7,270 lb. = 23·2%	12,825 lb. = 42·5 %
Ratio of clinker and dust to fuel burnt	12,805 lb. = 44·7%	7,270 lb. = 23·2%	12,825 lb. = 52·7 %
Ratio of clinker to fuel burnt	9,805 lb. = 34·2%	6,270 lb. = 20 %	7,025 lb. = 28·8 %
Ratio of dust to fuel burnt	3,000 lb. = 10·5%	1,000 lb. = 3·2%	5,800 lb. = 23·8 %
Rate of burning per hour	3,016·8 lb.	4,704 lb.	4,106 lb.
Rate of burning per sq. ft. grate area, per hour	40·2 lb.	62·7 lb.	54·6 lb.
Equivalent rate of burning per 24 hours	72,403·2 lb. = 30·17 gross tons	112,896 lb. = 50·8 gross tons	99,544 lb. 44·4 gross tons.
Details of Water and Steam.			
Total water evaporated	49,000 lb.	37,583 lb.	39,985 lb.
Water evaporated per hour	5,158 lb.	5,633 lb.	6,954 lb.
Water evaporated per 1 lb. of fuel burnt	1·71 lb.	1·20 lb.	1·69 lb.
Water evaporated per 1 lb. of refuse burnt	1·71 lb.	1·20 lb.	1·32 lb.
Average boiler pressure (Gauge)	122·6 lb.	118 lb.	1·30 lb.
Average temperature of steam (°F.)	601·6°	623°	605°
Average temperature of feed water (°F.)	170·4°	170°	170°
Factor of evaporation	1·235	1·234	1·22
Water evaporated per 1 lb. of fuel burnt from and at 212° F.	2·11 lb.	1·48 lb.	2·06 lb.
Water evaporated per 1 lb. of refuse delivered from and at 212° F.	2·11 lb.	1·48 lb.	1·61 lb.
Average combustion chamber temperature	1973° F.	2202° F.	1972° F.
Maximum combustion chamber temperature	2084° F.	2500° F.	2156° F.
Minimum combustion chamber temperature	1800° F.	2000° F.	1796° F.
Average temperature of gases after boiler and before regenerator	648° F.	652° F.	710° F.
Average temperature of gases after regenerator	481° F.	536° F.	532° F.
Chimney pull	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch
Details of Electrical Figures.			
Average temperature of air before regenerator	60° F.	66° F.	52° F.
Average air temperature after regenerator	237° F.	260° F.	240° F.
Average air pressure after regenerator	$3\frac{1}{2}$ inch	4 inch	$3\frac{1}{8}$ inch.
Speed of fan	350 r.p.m.	330 r.p.m.	310 r.p.m.
Gas Analysis.			
CO_2	..	..	9·8%
CO	..	..	0·0%
O	..	..	9·1%
N, etc.	..	..	81·1%
Total kilowatt hours generated	1180	920	875
Average kilowatt per hour	124	138	152
Maximum kilowatts per hour	150·0	225	240
Kilowatt hours per ton (2240 lb.) of fuel burnt	91·8	66	76·5
Kilowatt hours per ton (2240 lb.) of refuse delivered	91·8	66	61·6
Kilowatt hours per ton (2240 lb.) of fuel burnt on basis of 30 lb. of steam per kilowatt hour	127	89	128·8
Kilowatt hours per ton (2240 lb.) of refuse delivered on basis of 30 lb. of steam per kilowatt hour	127	89	98·8

The guarantees given were as follows:—

1. That the plant shall be capable of burning to a hard innocuous clinker 50 tons of the refuse of the city of Westmount per day of twenty-four hours, or 20 tons in ten hours.

2. That the combustion of the refuse shall be complete and free from nuisance, and that no odours or noxious gases shall be emitted from the chimney.

3. That the temperature in the combustion chamber in normal working with refuse of average quality shall not fall below 1500° Fahr., and that the average temperature will be from 1700° to 1800° Fahr.

4. That with refuse of average quality an evaporation of $1\frac{1}{4}$ pounds of water per pound of refuse from and at 212° Fahr. shall be obtained.

The refuse used in connection with test No. 2 was considered to be a fair average of that collected in Westmount.

Test No. 3 was carried out with a view to showing the advantages of screening the separately collected anthracite ashes. Instead of being tipped into the storage bin as in connection with the previous tests, the ashes and dust were passed through a screen which separated the fine incombustible dust from the combustible ashes. The ashes and dust were weighed before passing through the screen, and the combustible ash after, the difference of course being the fine dust.

The ashes were shovelled into the cells through the clinkering doors to avoid the trouble of raising the same to the tipping platform.

No useful purpose can be served by a critical comparison of the 1906 and 1910 test figures, because the refuse would obviously be of better quality in March and April than in May, hence the 1910 figures should show better results than those of 1906.

Vancouver, B.C.—The destructor here is of the Heenan back-fed type, and has been in use since November 1907. It is a 3-grate plant of the usual type, with combustion chamber, Babcock & Wilcox boiler and regenerator. The chimney is 120 ft. in height, and the total cost of the plant was $41,193·30, made up as follows:—

Building	$11,500·00
„ extras	4,543·30
Chimney	3,900·00
Destructor plant with boiler and accessories, also steam disinfector	21,250·00
	$41,193·30

Owing to the rapid growth of the city, it was decided to extend the destructor about a year since, and it was anticipated that the new plant

would be completed before the end of 1911. This work is being done by The Public Works Engineering Co., whose headquarters are at Portland, Ore., but there is little doubt that it will closely follow British design. During the winter months the refuse of Vancouver is estimated to contain upwards of 40 per cent. of ashes. The composition of the refuse in the summer is shown in the following table:—

TABLE XXVII.

Household garbage	82 per cent.
Trade refuse	12 ,,
Decayed fruit and vegetables	3 ,,
Manure	1·5 ,,
Sawdust	0·5 ,,
Meat and fish offal	1 ,,

The city engineer thus comments upon the apparent value of the refuse as fuel:—

"From the residential quarters, very good, about one-half ashes; from the business section, good light refuse; from the Chinese and Japanese section, poor, 75 per cent. black and heavy in moisture, containing much vegetable matter."

The destructor plant is centrally located, being about 200 ft. from the main thoroughfare through the city, and has buildings on three sides.

The following interesting features are extracted from the report of the city engineer:—

Cost of Operation per ton of Refuse Destroyed.

(*a*) 46 cents per ton deducting revenue.
(*b*) 56 ,, ,, not deducting revenue.
(*c*) 91 ,, ,, including interest and sinking fund.

Staff.

1 engineer at $85 per month.
2 firemen (qualified engineers) at $75 per month.
4 ,, at $70 ,, ,,
1 dumpman at $60 ,, ,,

With the exception of the dumpman, the staff work eight-hour shifts; the British Columbian law makes it compulsory for an engineer to be in charge of any steam plant of 10 H.P. or over.

The average weight of refuse burned per man per hour is given as 1·04 tons, which figure it is of interest to compare with the figures of mechanically-charged destructors.

Fan draught is provided, and the steam is used for the fan engine, a disinfector, and works purposes. The clinker is described as very hard, black, and well burned, the average percentage being 33. It has been

used for land reclamation at the works, and has been experimented with for road bottoming. The evaporation per pound of refuse destroyed is given as ·52.[1]

Seattle, Washington.—As already observed, the first British destructor erected in the United States was at Seattle; this plant has been in continuous operation since January 1908.[2] The destructor is of the Meldrum front-fed type, and comprises 4 grates, with a special offal hearth at that end of the grate furthest from the combustion chamber, a Babcock & Wilcox boiler, having 2201 sq. ft. of heating surface and a regenerator.

The building, originally of corrugated iron, and the inclined approach roads were constructed by the city engineer, as also the 80-ft. reinforced concrete chimney and the boiler foundation. The installation has been remarkably successful from every point of view, as will be evident upon perusing the accompanying reports prepared by Mr R. H. Thomson, the city engineer.

Table XXVIII. gives details of the first year's operation, while Table XXIX. covers 608 working days, from July 31, 1908, to August 1, 1910.

Reports of this kind are obviously far more valuable than records of short test runs, and these figures are well worth careful perusal.

Table XXIX.

OPERATING RESULTS, SEATTLE DESTRUCTOR, 608 DAYS, FROM JULY 31, 1908, to AUGUST 1, 1910.

Refuse consumed by furnace	42,580·523	tons.
Estimated tins, scrap, and glass going to dump	502·497	"
Estimated rubbish burned on dump	2068·562	"
Total refuse handled	45,151·582	"
Ash and clinker drawn from furnace	18,390·954	"
Ash and dust from combustion chamber and flues	931·023	"
Evaporated or consumed by the furnace, 51·5 per cent.	23,258·546	"
Average daily consumption, furnace and dump	74·263	"
Average daily consumption by furnace	70·034	"
Total number of loads of refuse disposed of	27,399	
Average number of loads of refuse disposed of per day	45·0	

[1] As showing the progress with British destructors in Canada it may be observed that during the past few months it has been decided to erect Heenan destructors at Ottawa, Moose Jaw, and Calgary.

[2] A second destructor of similar design is now in course of erection at Seattle.

T

ƷE DESTOIRE, *Assistant.*

th ; Lake Union on the north.

d r e.	Ash and Dust from Combustion Chamber and Flues	in in nerator.	Average Gas Analysis from Daily Readings. CO_2.	O.	O.	Average Water Gauge from Daily Readings. At Chimney without F.D.	Ashpit Pressure.
	...	...	...	...	...	...	...
	...	...	...	...	...	...	...
	...	8° F.	3·34%	...	...	$\frac{9}{16}''$	...
	...	7° F.	7·2%	7·05%	1·4%	$\frac{5}{8}''$	$1\frac{9}{16}''$
	...	·3° F.	6·4%	10%	·64%	$\frac{5}{8}''$	$1\frac{1}{2}''$
	...	·3° F.	8·3%	9·1%	·24%	$\frac{5}{8}''$	$1\frac{1}{8}''$
	...	2° F.	8·0%	5·4%	·6%	$\frac{1}{2}''$	$1\frac{5}{8}''$
	...	5° F.	8·7%	7·7%	·3%	$\frac{1}{2}''$	$1\frac{9}{16}''$
8	40·	6° F.	9·37%	6·1%	·54%	$\frac{1}{2}''$	$1\frac{7}{16}''$
6	62·155	5° F.	10%	5·47%	·7%	$\frac{9}{16}''$	$1\frac{3}{4}''$
2	55·88	4° F.	12·7%	2·74%	·57%	$\frac{1}{2}''$	$1\frac{3}{4}''$
2	48·64	3° F.	11·22%	3·47%	·81%	$\frac{1}{2}''$	2″
'	33·3	4° F.	9·91%	4·67%	·58%	0·7″	$2\frac{1}{8}''$

Average weight of the loads of refuse delivered	3296 lbs.
Total time expended for clinkering fires .	3054 hrs. 45 mins.
Total number of fires clinkered . . .	14,426
Average time required to clinker each fire .	12 mins. 42 secs.
Average time each fire was burning . .	3 hrs. 12 mins.
Average weight of clinker drawn from each fire	2550 lbs.
Daily evaporation by boiler (average for 608 days)	140,068 lbs.
Average hourly evaporation—from and at 212° F.	204 h.p.
Water evaporated per lb. of refuse . .	about 1 lb.

Expense and Revenue.

Wages as per pay-roll—total for burning refuse and handling bye-products . .	\$33,256.19
Total cost (per ton of refuse burned) of burning and handling bye-products . .	0.7365
Received from sale of clinker and clinker sand	2,466.00
Received from sale of power	719.42
Compensation per ton of refuse handled; cash from sale of clinker	0.546
Compensation per ton of refuse handled; cash from sale of power	0.159
Compensation per ton of refuse handled; property improved by fill	0.20
Compensation in cash per ton of refuse handled	0.705
Total compensation per ton of refuse handled	0.2705
Net cost, per ton, of handling the refuse at the destructor	0.466

The average composition of the refuse burned has been as follows:—Ash, 43·5 per cent.; manure, 4·0 per cent.; garbage, 32·1 per cent.; rubbish, 20·4 per cent. The average temperature from daily readings in degrees Fahrenheit has been, in the combustion chamber, 2376°; at the base of the stack, 547°; at the inlet to the regenerator, air temperature 74°; at the ash-pit, 268°. The gain in the regenerator has averaged 194°. The gas analysis has shown the percentage of CO_2 to be 10·2; of O, 4·7; and of CO, 0·6. Results of weather observations indicate that during the period covered by the accompanying data 325 days were clear, 198 cloudy, and 85 rainy. The average water-gauge readings show $\frac{1}{2}$ in. at the base of the stack without forced draught, and $1\frac{7}{8}$ in. back pressure at the ash-pit door of grate.

Borough of Richmond, West New Brighton (Staten Island).—This, the second British destructor erected in the United States, was completed in March 1908. After an exhaustive study of the refuse-disposal problem

in England. Mr J. T. Fetherston, the Cleansing Superintendent, strongly recommended the erection of a shovel-fed plant, and the contract was placed for a Heenan back-fed type of destructor having four grates, a

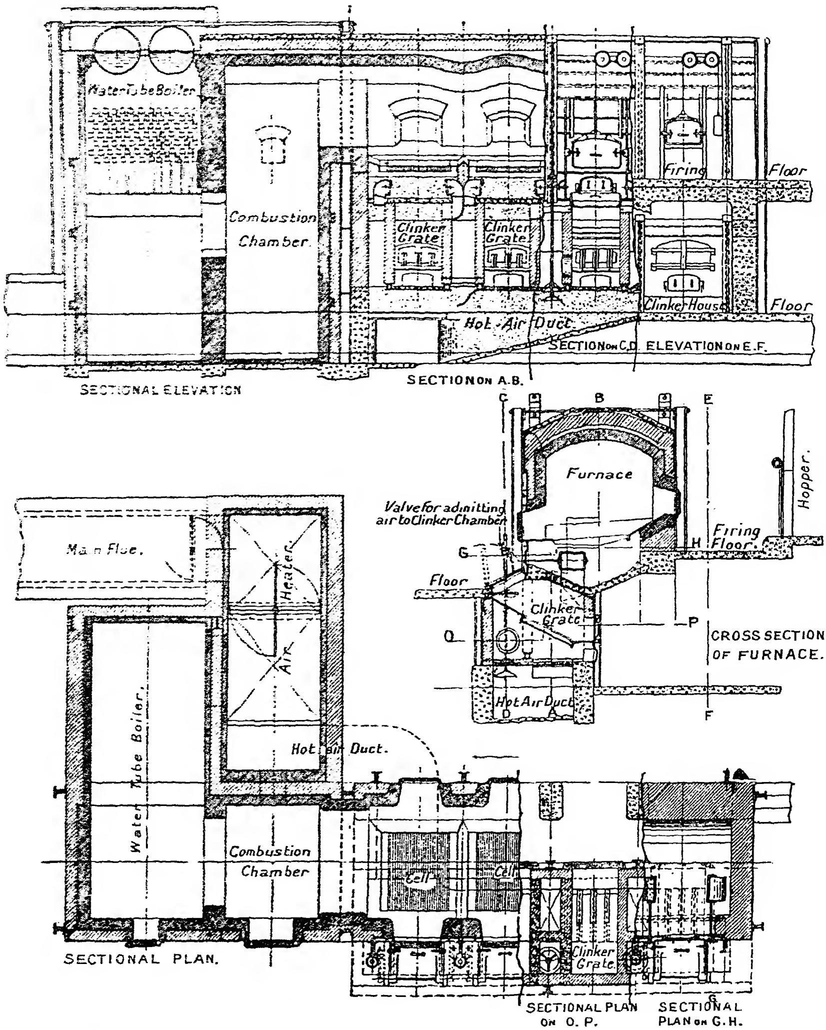

Fig. 75.—"Heenan" Back-Fed Destructor at West New Brighton (N.Y.). Sectional plans and elevations.

specially large combustion chamber, a clinker-cooling pit, and a Babcock & Wilcox boiler. A regenerator is installed for heating the air supply for combustion, together with a centrifugal fan direct-coupled to a vertical high-speed enclosed engine.

The total cost of the installation was as follows:—

Land 100 ft. × 300 ft.	$5,000.00
Foundations, building chimney, inclined approach, retaining wall, etc.	39,500.00
Destructor, boiler, etc, ...	23,995.00
	$68,495.00

Owing to the marshy character of the site, it was necessary to resort to piling, and 107 concrete piles, averaging about 26 ft. in length, were used. The building, inclined roadway, and connecting flue were constructed in reinforced concrete. The chimney also was built of reinforced concrete with a firebrick lining for a distance of 20 ft. from the base. Sectional plans and elevations of the destructor are shown in fig. 75. The inclined approach, building, and chimney are illustrated in fig. 76, while figs. 77 and 78 respectively, show the destructor furnaces at the clinkering floor, and the water-tube boiler with the forced-draught fan and engine.

The official tests of the plant occupied two weeks, and a summary of the figures is given in Table XXX., p. 201.

Mr J. T. Fetherston has devoted much attention to the scientific aspects of refuse disposal, and much of the work which he has done will doubtless have an important bearing upon the future of refuse disposal.

In the quantitative and qualitative analyses of refuse, Mr Fetherston has done not only more work, but more thorough work, than any other engineer, either in America or Europe. Latterly, he has been experimenting with devices for mechanical charging and clinkering. Unfortunately, when the author was at the West New Brighton, N.Y., destructor works in January of last year, the experimental cell was almost dismantled; hence it is not possible to furnish very complete information concerning the same.

The charging device in connection with the experimental cell had a capacity of 1 cub. yd. per charge. The refuse having been delivered into the hopper, was then fed as required into what is termed the pan, constructed of steel plate, the sides being formed of two 18-in. channels; these channels run between frames, containing roller bearings at the top, bottom, and outside; the rear end of the pan is provided with a movable pusher. The channels and pan with the charge of refuse are pushed forward into the furnace by means of an hydraulic ram, the pan, channels, and contents then covering the full grate area. On the backward or return stroke the pusher already referred to at the rear

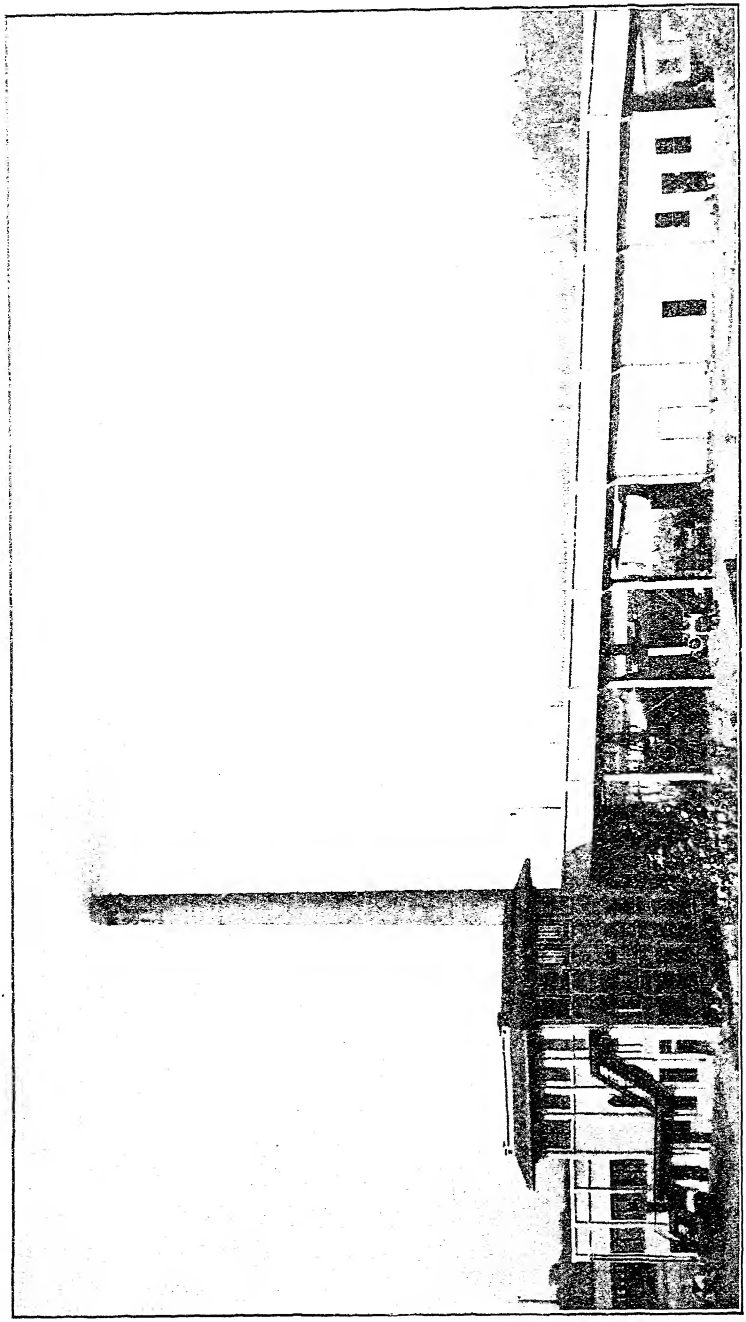

FIG. 76.—West New Brighton (N.Y.) Destructor Works, view of approach roadway, buildings and chimney.

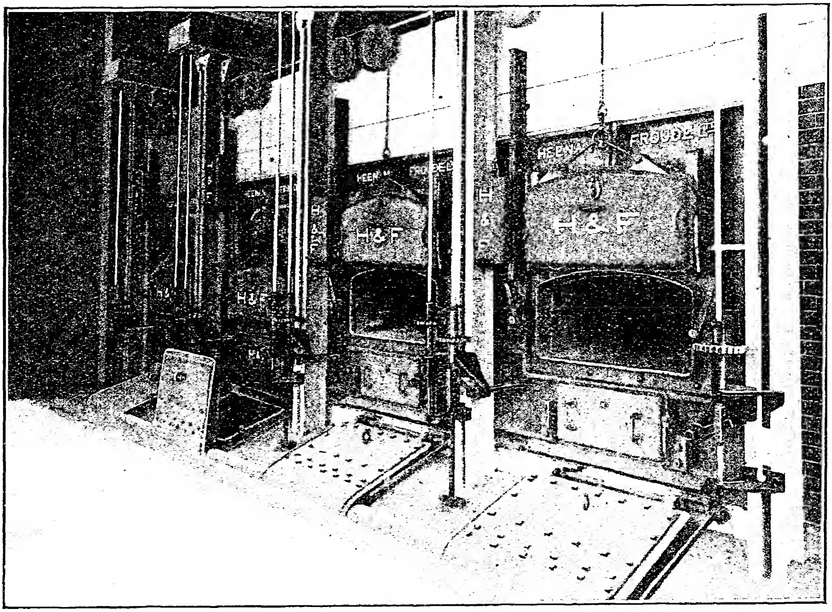

FIG. 77.—West New Brighton (N.Y.) Destructor, view of cells and clinkering floor.

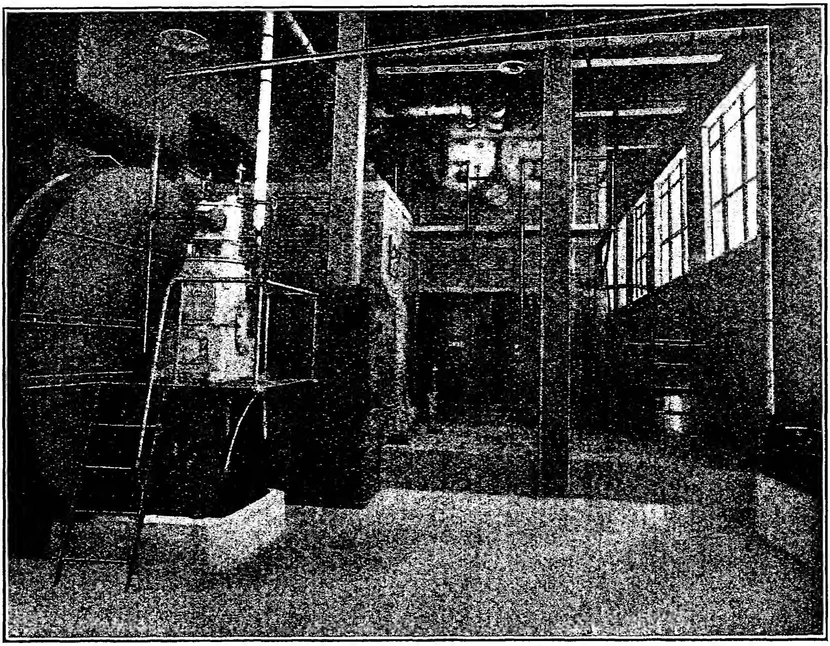

FIG. 78.—West New Brighton (N.Y.) Destructor, view of boiler, fan, and engine.

end or back of the pan is latched in position, with the result that the refuse is forced bodily off the pan on to the grate; immediately after this operation the pusher is unlatched and returns to take up its position in readiness for the next charge, this movement being effected by means of a rack and pinion actuating drums carrying cables to guide the rods of the pusher, or preferably by a small independent ram (or piston). The former arrangement was used in connection with the experimental cell at West New Brighton, while the charging device was actuated by an 8-in. ram (piston) with 200 pounds water pressure.

The clinkering device consists of channel-shaped flat grate bars, with two ridge bars projecting about 6 in. above the grate level, carried in a strong cast-iron frame attached to a piston rod, the frame running on rollers.

Each ridge bar is provided with a nose projection or hump on its extreme end, to break the clinker along the weak line created by the level of the top of the ridge bar, as compared with the grate level proper. Nine-inch angle deadplates surround the active portion of the grate. The ram pulls the grate into a closed chamber, allowing the clinker to drop directly into the cooling chamber below, after which operation the grate is returned to its normal position.

The clinker-removal device consists of a piston attached to a ram, so arranged that on the forward stroke the cooled clinker is forced through the outlet door of the clinker-cooling chamber into a car or skip for removal.

The diagrammatic sketches, fig. 79, illustrates the charging and clinkering devices as installed in connection with the experimental cell at West New Brighton, Staten Island.

As already observed, early in 1911 it was decided to erect an additional destructor for the borough of Richmond, Staten Island, N.Y., which will be known as the Clifton destructor. The principal features of this installation will be the charging, clinkering, and clinker-removal devices already described and illustrated. Another new feature will be the provision of suction-ash and dust-removal plant.

The Clifton destructor will comprise two 3-grate destructors, each guaranteed to destroy 45 tons per 24 hours, two combustion chambers, and two water-tube boilers, six clinker-cooling chambers, and six each mechanical charging, clinkering, and clinker-discharging devices, together with actuating machinery complete.

Each destructor unit of three grates will be provided with fan, engine, and regenerator. For the handling and treatment of clinker, a clinker

TABLE XXX.

Test No.	Date of Test, 1908.	Refuse burned. Description.	Composition.	Character. %	Character. Lbs.	Duration of Test.	Total Refuse handled.	Refuse burned.	Amount of Refuse burned per sq. ft. of Grate per hour.
			Components.	%	Lbs.	hrs.	Tons.	Tons.	Lbs.
1	May 6	September mixture as per specifications.	Garbage	46·6	19,875	8	21·325	20·802	52·0
			Fine ash	21·7	9,255				
			Coal and cinders	7·7	3,284				
			Clinker	0·6	256				
			Glass, metal, etc.	8·5	3,625				
			Rubbish	14·9	6,355				
			Total	100·0	42,650				
2	May 8	Refuse as collected.	Wet from rain; sample dried gave 38 % of moisture.			6½	16·315	16·145	49·7
			Components.	%	lbs.				
3	May 13	February mixture as per specifications.	Ashes	79·5	31,881	8	20·051	19·827	49·6
			Garbage	11·8	4,732				
			Rubbish	5·3	2,125				
			Glass, metal, etc.	3·4	1,364				
			Total	100·0	40,102				
4	May 15	Refuse as collected.	Wet from rain of previous day.			5½	17·430	17·235	62·7
5	May 16	Refuse as collected.	Relatively dry, representative material.			8	23·847	23·673	59·2

Test No.	Residual. Clinker, lbs.	Ashes, lbs.	Dust, (approx.) lbs.	Tins, etc., not fired, lbs.	Total lbs.	Percentage of Original Refuse.	Evaporation per lb. Refuse burned. Gross actual, lbs.	Gross Equivalent from and at 212° F., lbs.	Net useful Steam for Power from and at 212° F.
1	10,930	787	426	1046	13,189	30·9	1·17	1·41	1·31
2	8,390	787	326	340	9,843	30·2	1·03	1·25	1·16
3	41,466	1978	401	448	14,293	35·6	1·10	1·33	1·24
4	12,965	669	349	389	14,372	41·2	0·91	1·10	1·02
5	17,344	913	477	349	19,083	40·0	1·00	1·21	1·12

Test No.	CO_2. Average. %	CO_2. Maximum. %	CO_2. Minimum. %	Temperature in °Fahr. Combustion Chamber. Average.	Combustion Chamber. Max.	Combustion Chamber. Min.	Chimney Gases.	Outside Air.	Air leaving Heater.	Feed Water.	Average Steam Pressure in lbs. per sq. in.	No. of Fires clinkered.	Average Time per Clinkering, Min.
1	12·2	17·0	6·0	1846	2210	1526	393	48·5	306	55	137·4	9	9·0
2	12·3	16·5	8·0	1715	1922	1526	380	51·5	287	55	133·2	8	8·4
3	12·5	17·0	6·0	1637	1940	1382	364	83·9	268	56	130·5	10	11·9
4	12·4	17·6	8·6	1698	1904	1526	397	50·6	288	54	136·4	7	12·3
5	12·9	16·3	7·6	1792	1940	1634	...	...	...	54	137·4	5	8·2

railway, a crusher, elevator, magnetic separator, and screen will be provided. The estimated cost of this installation is as follows:—

Destructors, boilers, and accessories	$67,867.00
Chimney	4,000.00
Buildings	34,152.80
	$106,019.80

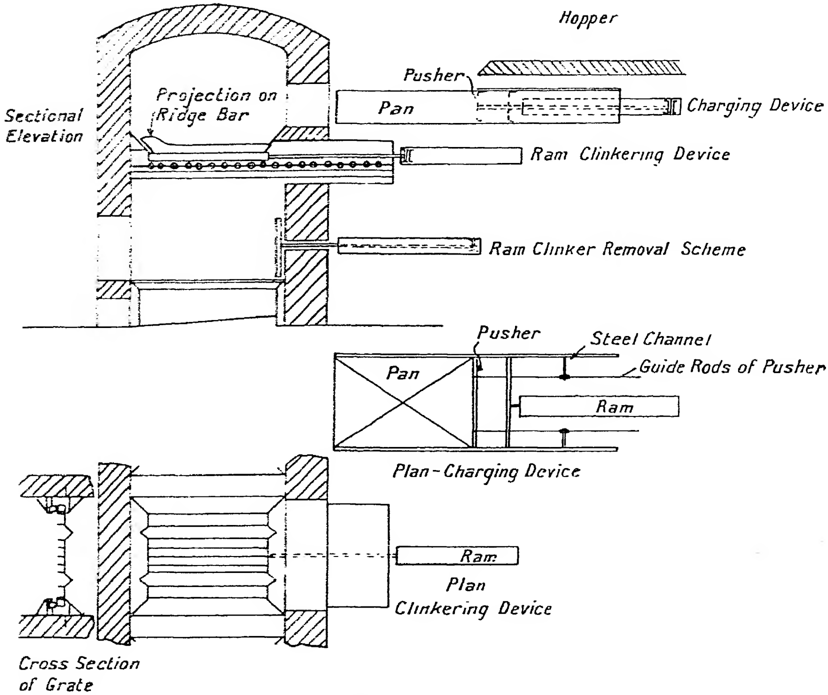

FIG. 79.—Experimental Cell, West New Brighton (N.Y.) Destructor. Sectional views.

The general lay-out of the Clifton destructor is illustrated in fig. 80. Embodying so many new features, the operation of this plant cannot fail to arouse considerable interest. The inception of the charging and clinkering devices may be said to be entirely due to the high labour cost in connection with the West New Brighton destructor. Owing to the high rate of wages ruling in the United States, and having in mind that but little use has been made of the steam and the clinker at West New Brighton up to the present, the cost of operation has been unduly heavy, and for this reason Mr Fetherston has devoted much attention to the problem of labour-saving.

It will be evident that a plant equipped on the lines of that proposed

for Clifton must involve a serious increase in the capital expenditure; whether or not this is warranted by the reduction in the operation costs remains to be seen.

There is a further point arising out of the labour question. When the author discussed the matter with Mr Fetherston in January of last year he was of opinion that in the operation of the charging and clinkering devices trustworthy and absolutely reliable men were of vital importance. Further, it was thought that if the clinker should be removed too soon, and before a fire was well burned down, the abnormal heat given off from an incompletely burned-out fire in the clinker-cooling chamber might be a source of possible trouble in connection with the grate immediately above.

Milwaukee, Wis.—In all probability the destructor at Milwaukee will have the distinction of being the largest destructor in the United States for some years to come; this destructor, which has a daily rated capacity of 300 tons, was put into operation in May 1910.

Of the Heenan top-fed type, the destructor consists of four units of six grates each. For each unit a central combustion chamber is provided, with three grates on either side. The general lay-out and arrangement of the plant is shown in fig. 81. The main building has two stories and a basement. The upper story is used exclusively as a feeding or charging floor, and for the storage of refuse. On the main floor, a portion of which is seen in fig. 82, the clinkering is done. The basement is used for the clinker railway, and for the cleaning out and removal of dust from the furnaces and boiler settings. The buildings and chimney both stand on pile foundations, above which are the concrete basement walls, and the superstructure framework of reinforced concrete, which consists of columns, floors, storage hoppers, and crane runways. The enclosing walls of the building are a red semi-vitreous brick, and the roof is of red reinforced cement tiles.

The essential parts of the plant are (1) two crane runways at the top; (2) the storage hoppers; (3) the mixing and feeding floors, with mechanically controlled shoots for charging; (4) the intermediate floor for the fans and fan engines; (5) the clinkering floors, on which are the boilers, furnaces, etc.; (6) the basement, in which are the clinker-removal cars; (7) the main flue, running east from the centre line of the building; and (8) the recording and measuring instruments.

The refuse is delivered into the storage hoppers above the furnaces by the cranes, operating on the crane runways over the hoppers; these can be seen in the cross-sectional view, see fig. 81. The crane runways extend over the roadways outside of the building at the north and south

ends, as will be clearly seen in fig. 83, which is an external view of the works. The garbage wagons arrive at the north end of the building, where the cranes lift the movable steel box body, and deposit the contents into the hopper.

At the south end of the building, at ground level, four dumping pits have been provided, in which stand steel dumping boxes. The wagons

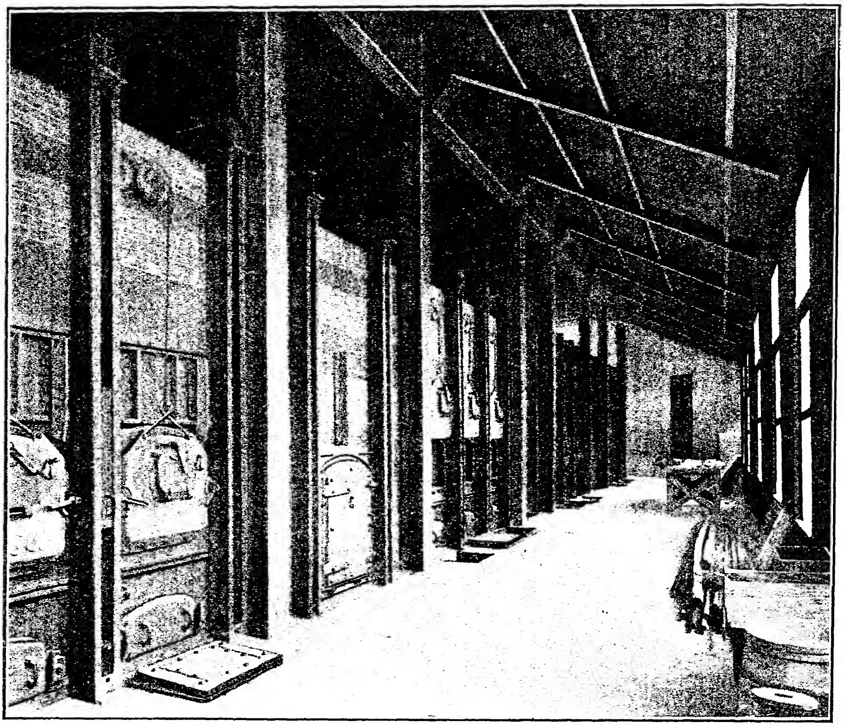

Fig. 82.—Milwaukee (Wis.) Destructor, view of cells and clinkering floor.

in Milwaukee which are used for the collection of ashes and rubbish are of the bottom-dumping type. Backing over the dumping pits, they deposit their loads into the dumping boxes, which are then lifted by the crane and the contents deposited in the storage hoppers. The storage hoppers, which are shown in fig. 81, are built symmetrically about the centre line of the building. There are three separate compartments for each of the four furnace units. All the hoppers are arranged to drain with a slope of 1 in 4 from the centre line of the building to gutters at the base of the slope, near the feeding-room floor.

The dividing up of the hoppers into compartments enables the garbage, ashes, and rubbish to be stored separately, and simplifies the mixing of the material in the shoots communicating with the charging openings in the cells. The drains provided at the base of the storage hoppers have proved to be very necessary, particularly with the garbage, which drains off a considerable percentage of moisture. The storage

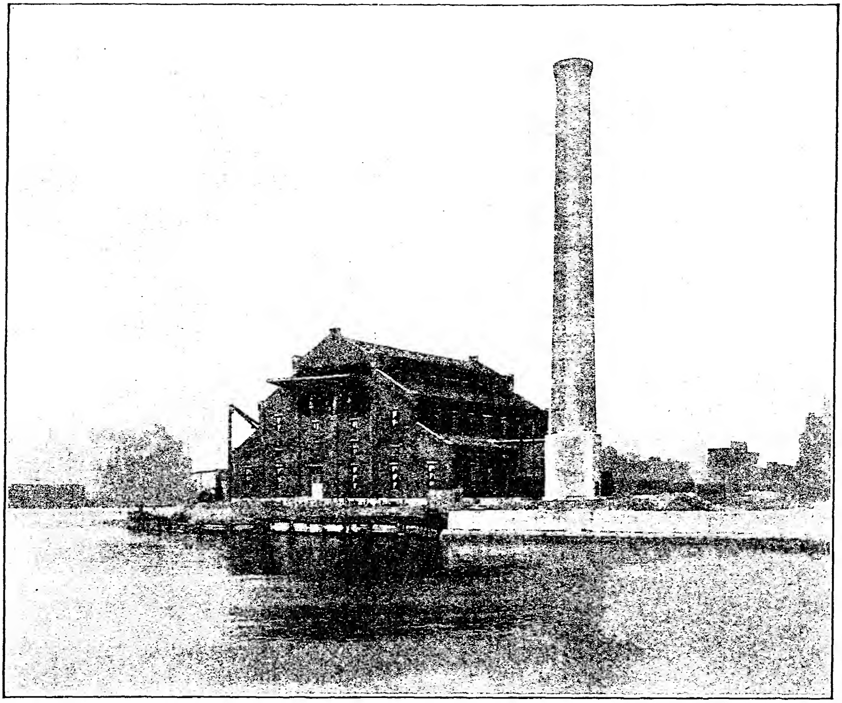

FIG. 83.—Milwaukee (Wis., U.S.A.) Destructor Works, view of buildings and chimney from south.

capacity of the hoppers is about 550 cubic yards, or 300 tons. Extending from the gutters at the bottom of the hoppers to the wall of the building is the charging-room floor, or feeding and mixing floor. The charging shoots, which are shown in figs. 81 and 84, and which communicate with the charging opening in the top of the furnaces, extend about an inch above the level of this floor. The refuse is raked and shovelled out of the storage hoppers into these charging shoots. In the filling of each charging shoot the man grades the refuse to suit the condition of the fire; this is a point of very considerable importance, as

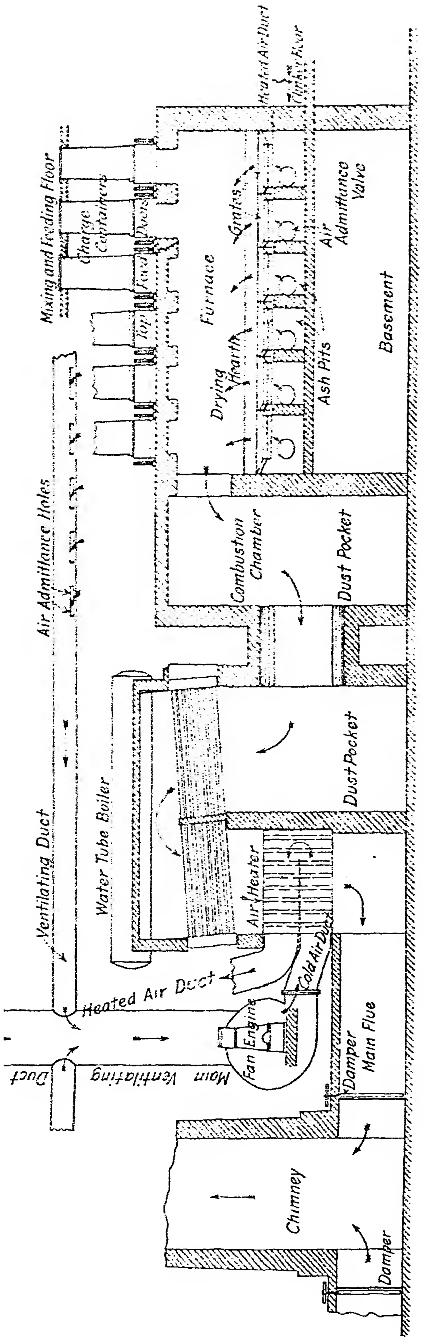

Fig. 84.—" Heenan " Top-Fed Destructor at Milwaukee. Diagrammatic section typical of one unit.

it enables a poor fire to recover rapidly if it receives a selected charge.

Six charging shoots are provided for each unit of six grates; each shoot is constructed of sheet steel 6 ft. long, 24 in. by 18 in. at the top and 30 in. by 24 in. at the base, and will contain about one cubic yard of refuse.

At the base of the shoot is a mechanically controlled door, which is operated by the firemen from the clinkering floor—see the cross-sectional view, fig. 81. This device consists of two steel shafts attached to four pinion wheels, rolling in pairs on two racks. The shafts hold a firebrick door, and are attached eccentrically to the pinions, so that when the pinions are pulled forward they lift the door from its seat and carry it forward at the same time. Guides to prevent the falling refuse from spilling follow the door as it moves away from the shoot.

The door consists of a cast-iron frame, filled with firebrick blocks; the outer edges of the frame extend below the firebrick and fit snugly into cast-iron seal troughs, filled with asbestos packing to seal the door tightly.

When the plant is being worked up to its rated capacity about nine charges per hour are put into each furnace; it should be observed that drying hearths

are provided, and every fresh charge of refuse is delivered on to a drying hearth, and not on to the grate direct.

FURNACES.—On the main floor of the plant, generally known as the clinkering floor, the four furnace units are located. These are arranged symmetrically about the centre lines of the building. Each unit consists of the furnace chamber proper, a water-tube boiler, an air heater, and the forced-draught apparatus. At the back of the furnaces are two ducts, the hot gas duct above and the hot air duct below. In front of the hot gas duct, and separated from it by a 9-in. firebrick wall, is the so-called drying hearth. The grates extend from the drying hearth to the dead-plate in front of the clinkering door. Below each grate is the usual separate ashpit, so that the forced draught for each grate can be separately controlled. The general arrangement of the several parts of the furnaces, and the course of the air supply and gases of combustion, are shown by fig. 84, which, however, is not strictly accurate as to structural details.

The gases of combustion from the grates come together in the large combustion chamber, in the centre of each unit, where their velocity is checked, and they are turned slightly downward by a baffle wall at the top. This not only gives ample opportunity for complete combustion of the gases, but has a decided tendency to deposit the dust from the gases into the lower part of the combustion chamber, which is carried about 10 feet below the grate level. From the combustion chamber the gases enter the first and second passes of the boiler, then pass through the inside of the tubes of the air heater, thence through a short flue into the main flue, and so to the chimney. In the short flue there is a damper which controls the suction draught for each unit.

The forced draught for combustion is driven by fans around the outside of the tubes of the air heater and into the hot air duct, from which it passes through valves into the ashpits, and so through the perforated grate bars to the fire. The hot gas duct above the hot air duct is operated by steam jets, which induce the hot gases from the combustion chamber through openings in the brickwork into the refuse standing on the back hearth. The purpose of this is to partly dry out the abnormally wet refuse as it stands on the back hearth before it is raked over on the fire.

The back hearth receives the fall of the refuse from the charging shoots above, and is built of a specially heavy design for this purpose. The refuse is left to stand and dry on this hearth until it is needed on the fire, when it is raked forward by the firemen.

The grates slope slightly from the back hearth to the furnace front, and are built of heavy cast-iron channels, perforated with $\frac{1}{8}$-in. holes for

the admission of the draught. They rest freely on the deadplate lip of the furnace front, and can slide forward and back on this as they expand and contract.

The furnace fronts are built of heavy castings secured to the vertical and horizontal steel framework of the furnace. In front of each grate is a wide clinkering door, in which is a small stoking door, which gives the stoker a good rest for his rake when raking new refuse over the fire. The ashpit door closes the ashpit practically gas-tight, and the valve controlling the forced draught operates through the furnace front just above the ashpit door.

BRICKWORK.—The furnaces and boiler settings are built in pink pressed brick, lined with firebrick, and are heavily braced with steel buck stays and horizontal channel irons. After a thorough investigation, three grades of firebrick were selected, as follows:—(1) C. Franklin Crown, a tough, hard, close-grained brick, used to line the sides and doors of the furnaces, and selected especially to withstand the wear and tear from stoking and clinkering. (2) Royal Star, a softer, coarse-grained, highly refractory brick, used in the arches of the furnaces where the heat is greatest. (3) Scioto Star, a good refractory boiler brick, used to line the second pass of the boilers and the flues. These bricks have the following chemical analyses:—

CHEMICAL ANALYSES OF FIREBRICK.

	C. Franklin Crown.	Royal Star.	Scioto Star.
Silica	53·25	55·25	56·17
Aluminium	41·01	41·78	40·86
Iron oxide	3·36	1·67	1·53
Lime	·41	·267	·289
Magnesia	·47	·501	·525
Alkali	1·50	·559	·618

Tests of these bricks were made with the following results:—

TESTS OF FIREBRICK.

	Absorption in 48 hrs.	Per cent. Elongation at 1800° F.
	Per cent.	Per cent.
C. Franklin Crown	6·93	0·4
Royal Star	8·64	0·67
Scioto Star	7·0	1·4

The bricks were all laid in fireclay, mixed to the consistency of cream. Each brick was dipped in the clay and then hammered into place with a heavy mason's hammer, so as practically to touch the surrounding brick on all sides. The maximum space between the bricks thus laid was $\frac{1}{8}$ in., but this was due to irregularities in the brick, and never extended over the whole bed. The average thickness of joint was less than $\frac{1}{16}$-in. It was found advisable to select the brick, so that each course should contain brick that was as nearly the same thickness as possible. Bricks burned at the same time should be kept together and used in the same parts of the wall.

The methods of bonding the firebrick together are interesting. In walls more than one brick thick, the bricks were held together by strips of $\frac{1}{16}$-in. band iron extending through over two bricks, the end of the iron being bent over as a hook at the exposed surface of the brick-work. This was done because a difference in temperature on the two sides of the brickwork would naturally produce different degrees of expansion and contraction. The ordinary header and stretcher bond would have given no opportunity for the brickwork to adjust itself to these movements between the inside and outside courses. In other places where the difference in expansion between the two sides of the wall was not great, header courses were built into every three stretcher courses. About the clinkering doors large blocks were used, and were laid to overlap each other so as to prevent the falling out of the brick under the jar of the clinkering tools.

The arches over the furnaces rest on cast-iron skewbacks built into the furnace wall. Each consists of two independent arches resting on separate skewbacks. The lower arch receives the full heat from the fire and protects the upper arch, which remains intact to hold the roof of the furnace in place.

Boilers.—Each furnace unit contains a 200-H.P. water-tube boiler. These boilers are hung from steel framework extending to the concrete footings above the piles. The boilers are hung high so as to provide ample space for dust settling and for the tubular air heater to stand below the boiler tubes in the second pass. Each boiler is equipped with three dust-blowing doors, so that the tubes can be kept free from dust and the evaporation maintained at the maximum. The boiler settings in the basement are all accessible through heavy doors for the removal of dust.

Air Heaters.—Below the tubes in the second pass of the boiler stands a tubular air heater. Each heater is approximately $8\frac{1}{2}$ by $8\frac{1}{2}$ ft. in plan, and 4 ft. high. It was found during the tests that these were

capable of preheating the forced-draught air supply to a temperature of 350° F.

FLUES.—Each furnace unit connects with the main flue through a short trunk flue leading from the boiler setting below the air heater. In this short flue is a damper so that the draught from each unit can be controlled. Each of these trunk flues has an area of about 30 sq. ft. The main flue extends between the furnaces on the east and west centre line of the building to the chimney. It has an area as it enters the stack of approximately 65 sq. ft. Just in front of the entrance to the stack is a damper so that the chimney draught can be controlled. The main flue is built of pink pressed brick, lined with firebrick, the walls being 13 in. thick. The brickwork is supported on a steel framework and is braced by vertical buck stays.

CLINKERING.—The clinkering doors are in the furnace fronts. In front of each clinkering door is a so-called clinker trap door, which covers an opening through the clinkering floor into the basement. In the basement, clinker cars operate on narrow-gauge tracks. During clinkering the clinker door and the clinker trap door are opened. The clinker and ash drawn from the grate fall through the trap door into the car standing below. At the present time, clinker is being dumped at the lake shore, about 200 ft. east of the plant.

VENTILATION.—The air for the forced draught is drawn by the fans from the clinkering rooms and from the feeding and mixing rooms (see figs 81 and 84). Ducts extend from the fans along the tops of the furnace fronts in the clinkering rooms; and also above the charging shoots in the feeding and mixing room. In this way the hot close air about the furnace is continually drawn out and forced through the fires.

FANS.—The forced draught is produced by four 48-in. sirocco fans, each having a capacity of 10,000 cub. ft. of air per minute, under a pressure of 5 in. of water at the fan outlet. These fans are directly connected to 5-in. high-speed vertical enclosed engines built by the American Blower Co. There is one fan and engine for each unit These all stand on a small concrete platform above the flue and between the four furnaces. The air is delivered by the fans into ducts leading to the air heaters. By means of a baffle, the cold air passes twice around the tubes of the air heater and then passes through a duct to the ashpits. The draught into each ashpit is controlled separately by a valve operated at the furnace front.

CHIMNEY.—The waste gases of combustion all pass into a radial brick chimney standing 154 ft. high above the clinkering floor level.

This stack is lined with firebrick to a height of 55 ft. It has an internal diameter of 10 ft. at the top.

INSTRUMENTS.—The plant is fully equipped with indicating and measuring instruments so that the operation of the furnaces can be watched and maintained at maximum efficiency. This feature is of considerable importance in conjunction with the power plant for the utilisation of steam, a feature which is being considered by the city officials. The instruments provided include the following:—A Fery radiation pyrometer, a Bristol electric indicating pyrometer, a CO_2 recorder, thermometer, and draught gauges.

SPECIAL FEATURES.—There are several special features to which particular attention should be called.

(1) The provision for draining the water from the garbage stored in the hoppers is a feature which takes full advantage of the local conditions of separate collection. It has been estimated that from 7 to 9 per cent. by weight of the water in the garbage drains away in this manner.

(2) The central location of the combustion chamber and its extension to the basement 10 ft. below the grate level provides ample opportunity for the settlement of dust and for complete combustion, to eliminate smoke. This feature has proven to be very successful.

(3) An objection sometimes made to mechanical charging is that the discharge of a large quantity of refuse at one time into the furnaces destroys the activity of the fire. This objection is obviated by receiving the fall and shock of the charge on the back hearth instead of on the grate. This not only prevents the disturbance of the fire, but also affords opportunity for drying the refuse somewhat before actually stoking it over the grate.

(4) The large areas of flues and passages throughout the furnaces, and the complete control of these with dampers, have proven to be features well worth their cost.

CONSTRUCTION OF THE DESTRUCTOR.

CONTRACTS AND PRICES.—The general contract for the foundations and framework of the building, and for the furnaces, boilers, machinery, etc., was awarded to the Power Specialty Co. of New York City for the approximate sum of $175,000. The building and appurtenances were let in twelve separate contracts, amounting altogether to $20,000. The chimney was built by the M. W. Kellog Co. of New York for $4485. The extras on the work amounted to approximately $4500, and the

engineering and inspection fees to approximately $5000. The total cost of the work has, therefore, amounted in round figures to $208,985.

Contract Tests.—In accordance with the specifications, each unit was tested once. The specifications required that there should be three official tests, and one test on a mixture prepared to represent the normal grade of refuse otherwise disposed of by the city, a condition which will hold when other destructors have been built. It was determined that this mixture for the average throughout the year would approximate to the winter mixture defined in the specifications. Consequently tests were made, using only the three mixtures of refuse designated in the specifications as extreme summer refuse, extreme winter refuse, and average annual refuse. The results of the three official tests are given in Table XXXII. (page 217). The fourth test was made as a provisional test before the plant was put into full operation, and proved the capacity and evaporative abilities of the plant satisfactorily.

While the three official tests were being made, the plant was handling all the garbage of the city. This made the conditions of testing rather arduous, because the plant had not had time to develop its best efficiency, and because other portions of the plant had to be kept in full operation. Three units were in regular operation during the tests, one at a time being singled out for testing.

The material burned during the tests consisted of garbage, ashes, rubbish, and manure taken from the regular collection wagons. No attempt was made to select any of the materials. Samples were taken during five different tests and analysed, the results being given in Table XXXI.

The samples were taken on the dates indicated and were analysed in the laboratory of the Semet-Solvay Co. The percentage proportions are by weight of the original sample.

Representative shovelfuls of the materials were taken, mixed, chopped, halved, quartered, and bottled for analysis.

The various ingredients of the refuse were not artificially mixed. The garbage was first deposited on to the floors of the two outer hoppers of the unit under test. Then the ashes, rubbish, and manure in the proper quantities were deposited on top of the garbage as they were received from the wagons. While the material for the tests was being weighed and stored in the two outside hoppers, the furnace was being operated by material previously stored in the middle hopper. At a specified time the charging shoots were filled with refuse from the weighed material, and the test was continued until all of the weighed material had been deposited into the charging shoots.

TABLE XXXI.—ANALYSES OF REFUSE TESTED.

	Moisture.	Carbon.	Volatile Matter.	True Ash.
(1) Garbage:—	Per cent	Per cent.	Per cent.	Per cent.
May 18	64·32	4·85	18·95	11·88
,, 24	68·67	4·22	18·20	8·91
,, 26	72·44	4·29	16·92	6·35
,, 27	75·74	3·39	16·49	4·38
June 1	71·87	3·95	17·25	6·93
Average	70·6	4·1	17·6	7·7
(2) Ashes:—				
May 18	15·43	12·75	6·48	65·34
,, 24	20·20	26·94	4·25	48·61
,, 26	15·79	23·33	8·76	52·12
,, 27	19·62	15·24	6·06	59·08
June 1	19·12	38·01	3 40	39·47
Average	18·0	23·3	5·8	52·9
May 24, sample of wet ashes	30·41	19·67	8·41	41·51
(3) Rubbish:—				
May 18	13·60	18·21	36·37	31·82
,, 24	18·03	16·04	29·72	36·21
,, 26	17·07	16·25	59·63	7·05
,, 27	50·83	8·90	19·52	20·75
Average	24·9	14·9	36·3	23·9
(4) Manure:—				
May 18	49·29	9·27	27·95	13·49
,, 24	53·63	11·52	27·78	7·07
	49·57	10·18	33·54	6·71
,, 26	57·02	10·83	22·65	9·50
,, 27	58·57	7·34	28·13	5·96
June 1	50·50	11·34	33 30	4·86
Average	53·1	10·1	28·9	7·9
(5) Street Sweepings:—				
June 1	33·05	9·31	14·6	43·04

Records of the temperature and evaporation were taken regularly throughout all the tests. Temperatures in the combustion chamber were read on a Bristol electric pyrometer, calibrated to read up to 2400° F. These readings were taken every 15 minutes. The points of the instrument extended through the sight hole of the combustion chamber door about 3 ft. into the combustion chamber. They therefore did not extend into the hottest part of the chamber, and the readings of temperature are consequently on the safe side. All other readings were taken every half-hour. The measurements were made by the superintendent, Mr Greeley, assisted by four men, two of whom were from the city

meter-testing department, one of whom was electrician at the old garbage plant, and the other was employed especially for this purpose. The Bristol pyrometer was calibrated against three high-temperature instruments at the Semet-Solvay Co.'s works, and was found to be approximately correct. The feed-water meter was calibrated at intervals throughout the tests.

The labour used on the furnaces was not skilled in this kind of work. The firemen had about one month's experience on the furnaces before the tests were started, and were workmen without previous experience in high-temperature firing. The man shovelling on the feeding and mixing floor was an ordinary labourer, selected from a dozen or more working about the plant. During the tests to determine the cost of incineration, in accordance with the requirements of the specifications, one man charged the charging shoots on the feeding and mixing room floor, and three men operated the furnaces below. These men operated the furnaces during the whole period of the test on average annual refuse. During the clinkering, one of the three men on the furnace worked in the basement, handling the clinker car, which, when full, was pushed to a point just outside the building as required. The evaporation for determining the steam credit was based on measurements taken on May 26. The results of the tests are given in Table XXXII., showing the summary of the official tests of the Milwaukee refuse destructor. No measurements were made of the quantity of clinker produced, because, with the other two units operating, it was impossible to isolate and weigh the clinker from the unit under test.

Supplementing the data in Table XXXII. with respect to the conditions and guarantees called for in the specifications, reference may be made to several of the principal features, as follows:—

The capacity of the furnaces was guaranteed to be such that 60 lbs. of refuse would be burned per sq. ft. of grate area per hour. This rate was easily obtained, and the indications are that in practice a rate in excess of this figure can be quite regularly obtained.

It was specified that the temperature in the combustion chamber should not drop below 1250° F., and that an average temperature should be maintained of at least 1500° F. This feature was entirely satisfactory.

The furnaces, when working at their normal load, were required to produce a residual that is thoroughly burned, hard, and free from organic matter. Chemical analysis of representative samples of residual showed the percentage of volatile matter to be 0·06 per cent. in clinker, 1·77 per cent. in ashpit ash, and 0·74 per cent. in the grate ash.

The steam production, equal to 1·25 lbs. of steam generated from and at 212° F., for each pound of refuse of the annual average composition, easily met the guarantee, and sets forth the most distinctive feature of the Milwaukee refuse destructor. The production of 0·87 lbs. of steam per lb. of refuse of the extreme summer composition well illustrates this feature of the plant, and is a result which appears most striking to those interested in this question.

No odours, obnoxious gases, smoke or dust escape from the chimney or building. The combustion chamber serves successfully as a dust settling chamber.

No nuisance was created at the works during ordinary operations. In the basement where the clinker is removed, at times there was more or less dust noticeable as the clinker dropped through the trap door into the cars standing below. This feature will undoubtedly show improvement as the plant continues in service, and the operators become more familiar with its proper performance. Taken as a whole, the destructor was found to be strikingly free from anything that could be designated as a nuisance.

The flues, dust collectors, furnaces, and combustion chambers are arranged in an accessible manner, and so that dust and ashes may be removed without any unreasonable delay.

Table XXXIV. shows the computation of the cost of incineration, in accordance with the requirements of the specifications.

This cost, as is true of all other records of the tests, is computed according to the prices and conditions clearly set forth in the specifications, a synopsis of which was published in *Engineering News*, New York, for April 22, 1909.[1] On account of the limitations set forth in the specifications, the actual cost of operation is not given by these figures.

Operation.—Experience during May and June 1910 indicated that the total cost of operating the new plant will not exceed $4700 per month during the summer, and that the average throughout the year will not exceed $4400 per month, making a total yearly cost of operation and maintenance of the new plant of $52,800.

As the destructor continues in service it will no doubt be operated more economically than at the outset, when it is necessary to train new men to new duties. With the annual cost of operation and maintenance as above estimated, it is found that the cost of operation and maintenance per ton of mixed refuse is about 57 cents, on the basis of operating the plant at its full-rated capacity of 300 tons per day for each working day

[1] See *Engineering News*, New York, April 22, 1909.

in the year. Whether or not this figure will be reached during the first year of operation depends largely upon the actual quantity of refuse incinerated. Using the 1909 figures for the cost of operation and maintenance of the old garbage plant, including the cost of transportation across the river, an expense now eliminated, the cost of operating the old plant for the disposal of garbage alone on a yearly basis amounts to $64.256. This figure makes no allowance for power used for crane service and lighting at this plant; the power was being furnished from an adjoining sewage-pumping station without charge. Power for these services at the new plant is developed from the combustion of the refuse. Further, in the estimates of the old plant, no charge was made for the tug for towing the garbage across the river, as that was furnished by the city fire department without charge.

Comparing the operation of the old and new plants, it appears that there is a saving of at least $11,000 per year, which at 4 per cent. will pay the interest charges on an expenditure of $275,000—a sum sufficient not only to pay for the cost of the new plant, but also to pay for the cost of the installation of a power plant to utilise the excess steam generated.

The destructor will develop an excess supply of steam from the combustion of the refuse, which will be of real value for operating sewage pumps, electric lighting, or other municipal works. The value of the steam depends upon its use, and no estimate has been included, although it is one of the chief credits of the plant. Assuming that, of the four complete units, one is held as a reserve, and one is used for operating the destructor accessories; there remains 400 boiler H.P. available for use elsewhere, which will operate a 500-kw. generator. Assuming the value of power to be one cent per kw. per hour, this represents a value for the excess steam of about $3500 per month, or $42,000 per year.

In setting forth the merits and advantages of the new destructor at Milwaukee, it is necessary to recognise the sanitary advantages of disposing of the rubbish by incineration, particularly with respect to such articles as mattresses and other materials subject to infection. As cities increase in size, it becomes more and more difficult to find accessible dumping grounds for the disposal of ashes and rubbish. The ability to dispose of ashes and rubbish in a modern incinerating plant without any difficulties as to nuisances from odours, smoke, or dust is an item of much financial importance. It means that it is quite feasible, with the proper location of a series of incinerating plants, to reduce considerably the haul for the teams making the collection, as compared with hauls necessary to suitable dumping places. Milwaukee, as well as many other cities, offers opportunities for effecting a saving in collecting rubbish and ashes to

such an extent that the saving will more than pay the interest on the cost of the installation of modern incinerating plants at points where they can be located and utilised to best advantage.

These figures and comparisons are not given as a detailed study for the future development of refuse disposal in Milwaukee, but simply to indicate the inherent value of a modern incinerating plant along economical as well as hygienic lines.

The author is indebted to Mr Samuel A. Greeley, jun., A.M.Soc.C.E., Superintendent of the refuse-disposal works at Milwaukee, for the foregoing very complete description of the destructor works, which he was privileged to inspect in January 1911.

TABLE XXXII.—SUMMARY OF OFFICIAL TESTS OF MILWAUKEE REFUSE INCINERATOR.

May and June 1910.

Date	May 19 and 20.	May 23 and 24, June 3.	May 26 to June 1.
Duration, hours	37.	36 hrs. 26 mins.	37.
Grade of refuse tested	Extreme Summer.	Extreme Winter.	Average Annual.
Refuse burned, total tons	123·62	126·87	126·81
Percentage of garbage	56·7	29 7	40·8
,, ashes	30·6	59·7	41·0
,, rubbish	5·9	6·8	4·8
,, manure	6·8	3·8	13·4
Rate of burning, tons per 24 hrs.	80	84	86
Lbs. per sq. ft. of grate area per hr.	63	65	64
Number of fires clinkered	57	62	63
Average time per clinkering, mins.	7·8	9	7·3
Evaporation per lb. of refuse—			
Gross actual, pounds	·79	1·19	1·10
Equivalent from and at 212° F., lbs.	·96	1·45	1·34
Net useful from and at 212° F., lbs.	·87	1·36	1·25
Temperature feed water, degrees F.	52	49	49
Average steam pressure, lbs. per sq. in.	146	133	130
Carbon Dioxide—			
Average, per cent.	9·3	8·8	12·9
Maximum, ,,	16·0	19·8	17·2
Minimum, ,,	6·2	5·5	3·5
Temperature, degrees F.—			
Combustion chamber average	1,607	1,668	1,664
,, ,, minimum	1,267	1,240	1,267
,, ,, maximum	1,880	2,060	2,000
Chimney gases	581	597	515
Forced draught, leaving heater	398	358	351
Pressure of draught leaving heater, ins. of water	4·2	4·9	4·6
Furnace units under test	No. 4	Nos. 1 and 2	No. 1

The following Table XXXIII. gives the details of the five months' working, with comparative figures showing the cost of disposal for the corresponding period of 1909.

TABLE XXXIII.—MILWAUKEE REFUSE DESTRUCTOR.

Data for First Five Months' Operation, June to October 1910.

	Total Quantity in Tons.	Average per day, Tons.	Per Cent. Garbage. (all by weight).	Per Cent. Ashes.	Per Cent. Rubbish.	Per Cent. Manure.	Total Cost Disposal of Garbage, 1909.	Cost Disposal of Refuse, 1910.	Balance in favour of 1910.	Cost per Ton of Refuse, 1910.
June . . .	5,170	198	59	25	9	3	$5,691.60	$4,956.04	$735.56	$0.96
July . . .	4,760	183	67	17	11	5	6,451.84	5,146.48	1,305.36	1.07
Aug. . .	4,861	180	71	14	12	3	6,662.64	5,074.96	1,587.68	1.04
Sept. . .	5,341	205	67	20	11	2	6,914.24	4,698.74	2,215.50	0.88
Oct. . . .	5,370	206	64	22	12	2	5,453.60	4,405.21	1,048.39	0.82
	25,502	194	66	20	11	3	$31,173.92	$24,281.43	$6,892.49	

TABLE XXXIV.—TEST COST OF OPERATION OF MILWAUKEE REFUSE INCINERATOR.

Average Annual Refuse.

Tons incinerated during test	126·81
Labour required :—	
1 feeder, 37 hrs., at 25 cents	$9.25
3 firemen, 37 hrs., at 25 cents	27.75
¼ engineer's time, 37 hrs., at 37½ cents	3.47
Total cost .	$40.47

Cost of labour per ton	31·9 cts.
Steam from and at 212° F. to operate fan engine and feed pump per ton	219 lbs.
Cost of steam used per ton at 4 cts. per 100 lbs. .	8·8 cts.
Total cost to incinerate 1 ton	40·7 cts.
Total steam generated from and at 212° F. per ton	2·680 lbs.
Value of steam per ton of refuse burned at 4 cts. per 100 lbs.	107·2 cts.
Net profit per ton of refuse burned	66·5 cts.

Buffalo, N.Y.—Here the destructor is of the Heenan top-fed type, and consists of a 3-grate destructor, combustion chamber, water-tube boiler, and regenerator. The plant is located at the Hamburg sewage pumping station, with which works are also combined a refuse sorting and utilisation works.

When the author inspected this installation in January 1911, sorted rubbish only was being destroyed. In July 1913, when the existing contracts for the disposal of garbage expire, it is proposed to destroy the garbage and ashes. With this object in view it has recently been decided to duplicate the destructor at the Hamburg pumping station, and it is proposed to erect a third destructor on another site, preferably where facilities exist for the utilisation of the steam.

The sewage pumping plant at the Hamburg pumping station—about

FIG. 85.—Buffalo (N.Y.) Refuse Utilisation Plant. Tipping floor.

50 H.P., together with the plant in the adjoining refuse-sorting station—enables a fair proportion of the steam available from the destructor to be profitably utilised. The revenue from the steam supplied to the sewage-pumping plant is recorded in the accompanying financial report for the year ending 30th June 1910.

To one who has always objected to the sorting of refuse by female labour, the works at Buffalo were of great interest; the sorting is very thoroughly done under fairly satisfactory conditions, and the nature and value of the materials recovered is a revelation.

Fig. 85 is a view of the ground floor at the Buffalo works, at which

point the rubbish is delivered: all the rubbish is carried to the sorting floor above by means of the band conveyor shown in the background.

There can be no doubt that the works at Buffalo are, as a municipal undertaking, maintained in a more satisfactory condition than would be the case if they were in the hands of a contractor.

The following financial report of the refuse sorting and utilisation plant for the year ending 30th June 1909 is of much interest:—

TABLE XXXV.

Charges.	
Pay roll	$26,838.75
Maintenance and repairs	6,085.85
Interest on bonds, $50,000 (cost of plant)	2,000.00
New equipment	3,606.00
Sales.	
5,882 bales newspaper =2,656,010 lbs.	$10,020.39
13,865 „ mixed paper =6,438,950 „	20,187.38
1,121 „ Manila paper = 427,160 „	2,880.23
421 „ rags = 195,392 „	1,121.98
65 „ flour bags = 60,529 „	580.43
58 „ charcoal bags = 16,895 „	159.69
13 cars tins = 256,450 „	503.90
Scrap iron = 60,670 „	60.00
Old rubbers, etc.	65.00
19,552 beer bottles	195.52
169,264 mixed „	530.94
967 half-gallon bottles	19.34
4,453 ammonia „	22.28
Broken glass =20,000 lbs.	20.00
10 bales old shoes = 8,270 „	28.16
Total	$36,395 24
Deductions for moisture, etc.	21.90
	$36,373.34
Steam furnished to Hamburg pumping station at 70 cents per hour	2,802.63
	$39,175.97
Accounts receivable.	
Accounts outstanding July 1, 1909	$4,280.02
Sales for the year ending June 30, 1910	36,373.34
Total	$40,653.36

Montgomery, Ala.—A destructor of the Heenan top-fed type was completed here early in 1911, the capacity of which is 60 tons per 24 hours.

Located about 150 feet only from the municipal waterworks pumping station, it is hoped that it will be possible to fully utilise the steam available.

The destructor may be described as a 4-grate unit with drying hearths. The usual combustion chamber is provided, also a water-tube

boiler of 180 H.P. capacity, fitted with a superheater of the Foster type. The air supply for combustion is heated in a regenerator and delivered to the ashpits by means of a centrifugal fan, with the usual separate controlling levers for each ashpit.

The main floor of the destructor building is about 15 ft. below the level of the adjoining street, the roadway being carried through at this point on an embankment; a bridge connects the street with the upper floor or tipping platform. Upon crossing this bridge the refuse vehicles enter directly on to the tipping platform, and dump their contents into a storage hopper immediately beneath.

From this hopper the refuse is raked into containers, which are arranged directly over the charging holes in the top of the furnaces; immediately underneath are the drying hearths at the back of the grates.

The capacity of the container is about one cubic yard; the base of the container is arranged to swing open, so that the contents may be discharged on to the drying hearth.

The arrangements for saving labour in connection with the handling of the clinker are somewhat similar to those already described in connection with the Milwaukee destructor. Immediately upon being pulled out of the furnaces, the clinker is discharged through a shoot communicating directly with a tunnel underneath the clinkering floor. In this tunnel is a clinker railway, a car standing under a shoot. When filled, the car is drawn by means of a cable up an incline from the tunnel, and the clinker is automatically dumped into a clinker crusher, after which it is screened and deposited in the storage bins.

The chimney is built of radial brick, and is 100 ft. in height and 4 ft. internal diameter throughout.

San Francisco, Cal.—About a year since, the contract was awarded for the erection of two modern top-fed destructors of the Heenan type, but a destructor designed on the lines of the Fryer destructor was erected in San Francisco by Mr Thackeray, an English engineer, some fourteen years ago, comprising 32 large cells. This plant, which was operated by a company, was partially destroyed by the earthquake in 1906.

Some three years prior to the erection of the Thackeray destructor in San Francisco, a 12-cell plant of the same type was erected by Mr Thackeray in Montreal, and this installation is still in operation.

After considering the refuse disposal question for some years, the city authorities of San Francisco invited tenders in June 1910 to a very elaborate, complete, and stringent specification, prepared by Mr Marsden Manson, the city Engineer.

While it is ultimately intended to provide further destructors for the city, the specification in question provides for the erection of two destructors, each comprising two 4-grate units, and having a separate daily capacity of 120 tons. These two installations will be known as the North Beach and Islais Creek destructors. The building in connection with the former installation is to be designed to contain two additional 4-grate units, which will be erected at a later date.

To some extent the design of the San Francisco destructors will follow the same general lines as the Milwaukee installation, but the use of crude oil as fuel is to be arranged for, and two oil burners are to be provided for each unit.

In connection with each unit a water-tube boiler of not less than 1700 sq. ft. of heating surface will be installed, together with a regenerator. It is intended to fully utilise all the surplus steam after providing for the requirements of the works. The clinker and ash will also be utilised, and clinker crushing and screening plant will be installed, as also a tin baling press.

The equipment of the San Francisco destructors will be probably more extensive and complete than that of any other destructor works either in America or Europe. The guarantees required and the conditions imposed are exceedingly stringent, and the operation of the works will be watched with unusual interest.

AMERICAN FURNACES.

Generally speaking, American furnaces may be divided into two classes—crematories and incinerators; the former being recommended for the disposal of garbage, while the latter are intended to dispose of night soil and offal, in addition to garbage.

While it is claimed that both types of furnaces are operated at a high temperature, and are free from nuisance, these claims are not borne out in practice, and anyone at all conversant with the cardinal principles governing combustion would not anticipate any such working results. For the most part the furnaces are exceedingly crude in design and construction, and present conditions which are absolutely opposed to those conditions which must obtain in order to ensure satisfactory combustion.

In the burning of garbage it is found that almost invariably the charges are far too heavy, while preliminary drainage, which is of vital importance, has only recently appealed to one or two makers of American furnaces as being worthy of a trial.

For the disposal of each ton of garbage it is suggested that from 100 to 150 pounds of coal, or the equivalent, must be burned, and it is claimed that garbage containing 75 per cent. of moisture can then be destroyed without the emission of either smoke or noxious gases from the chimney. In practice, it is found that much more fuel is required, and the discharge from the chimney is usually very offensive.

As contracts are usually awarded to those makers who quote the lowest figure per ton of garbage disposed of for fuel and labour, it will be obvious that (1) the labour cost can best be kept down by charging the garbage in large quantities instead of its introduction in small and suitable charges; (2) that by proceeding on the assumption that "water can be burned" (which claim is made in these terms by more than one maker in their catalogues), the guaranteed cost of fuel per ton of garbage destroyed is kept at a much lower figure than is reasonable.

While it is true that wood and sawdust—both containing much moisture—are satisfactorily burned for steam generation, and while it is equally true that Bagasse is found to be a very useful fuel, the point to be observed is that either of these fuels, although possessing a definite calorific value, and usually containing far less moisture than garbage, would be of little, if any, service at all for steam generation if burned under the same conditions as garbage.

As a matter of fact, Bagasse is usually burned under far more satisfactory conditions than obtain in connection with the average American furnace, while wood and sawdust would be utterly useless as fuels if burned under crematory conditions.

Garbage, which by no stretch of the imagination can be termed a fuel, is compared with fuels of known composition and value; instead of being burned under such conditions as would reduce nuisance to the minimum, it is introduced in heavy charges, and dense volumes of heavy, objectionable gases are distilled.

In their passage to the chimney, these gases are caused to travel over the coal or other fire or fires, which are termed "stench fires" or "fume cremators." These fires, with their small grate area, can obviously have no appreciable beneficial deodorising effect upon the great volume of objectionable low-temperature gases passing over the top of the fire at a considerable velocity.

Twenty years since in England, when fume cremators burning coke were introduced in connection with the early low-temperature destructors, it was clearly shown that this provision was of very doubtful value, even when burning mixed refuse containing 33 per cent. of moisture.

Garbage will never be satisfactorily burned unless mixed with other

refuse in suitable proportions as at Milwaukee, and until it is clearly recognised that a high temperature must be maintained in the furnace and in a suitable combustion chamber. If this is done, "stench fires" and "fume cremators" are not required. It will be found that comparatively small, regular, and fixed charges are essential; and while, to some extent, this method of operation will increase the cost of operation, it will be amply compensated for by (1) the fact that no coal or other fuel is required, and (2) the entire absence of nuisance from the chimney.

Whether or not ashes will be required in addition to rubbish to burn with the garbage must obviously depend upon the percentage of rubbish available. At Milwaukee, Mr Greeley has found that 20 per cent. of ashes give a satisfactory result, but it must be borne in mind that Mr Greeley has endeavoured to dispose of a very high percentage of garbage.

To those engineers who have closely followed the design and exploitation of American furnaces, it is not surprising to find that at the present time the competition is limited to a very few, the principal of which are the Dixon Engineering and Construction Company, Messrs Lewis & Kitchen, the Public Works Engineering Company, and the Decarie Manufacturing Company. The Dixon Engineering and Construction Company, who for many years past have been engaged in the design and installation of crematories and incinerators, have recently designed a top-fed destructor of the steel-cased type, lined with firebrick. The charging platform is constructed either in steel or concrete. The garbage is charged into hoppers at the top of the furnace and falls into a drying and storage compartment. On both sides of this compartment or chamber is a cast-iron flue, through which hot gases pass, the object being to dry the stored garbage.

The drying and storage chamber is separated from the destructor proper by a firebrick arch. In this firebrick arch are charging holes, with cast-iron covers lined with firebrick. The covers are raised by means of a chain hoist, and when it is desired to charge the destructor grates below, the covers are raised, the garbage falling on to the destructor grates, which are of the American shaking type. Under these grates forced draught is supplied, steam-jet blowers being used for this purpose. Ashes and combustible waste are charged direct on to the destructor grates.

Messrs Lewis & Kitchen, who have been closely identified with the design and erection of crematories and incinerators for several years, have, during the past year, erected a plant for the city of Topeka, Kansas, which embodies some unusual features in crematory design. In fig. 86, sectional views of this installation are shown, which, however,

do not show the charging devices which have been introduced in connection with this installation.

The Topeka crematory consists of two furnaces, with containing building, inclined approach road, discharging platform, storage bins, and chimney. The two furnaces have a rated capacity of 60 tons per 24 hours, and the storage bins are designed to contain 40 tons of

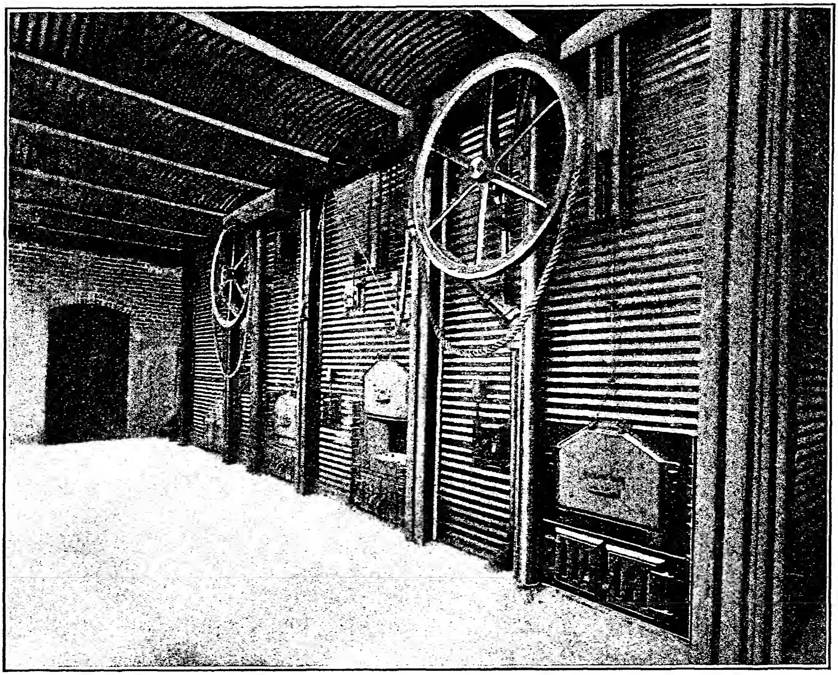

FIG. 87.—Topeka (Kansas, U.S.A.) Crematory, view of furnaces.

garbage, in addition to which the feeder hoppers have a capacity of 8 tons. The two furnaces are arranged back to back, while it will be observed that ordinary grates, with primary and secondary drying hearths, are provided, as also a combustion chamber and dust arrester. It will be noticed that each furnace is provided with a storage bin. The charging or feeding devices, which are not shown in fig. 86, are arranged at the base of the top storage bins, and are of a simple piston type, operated by an electric motor with gearing, which is controlled by a simple chain device from the stoking floor.

After partially drying on the upper or primary drying hearth, the material is stoked on to the secondary hearth beneath, where the drying

process is completed. The whole volume of gases pass from the left-hand furnace through the right-hand furnace, in their travel being deflected down upon the drying hearth in the right-hand furnace.

The main storage bins at Topeka are constructed of reinforced concrete, and are provided with drains to carry away liquid direct to the sewer.

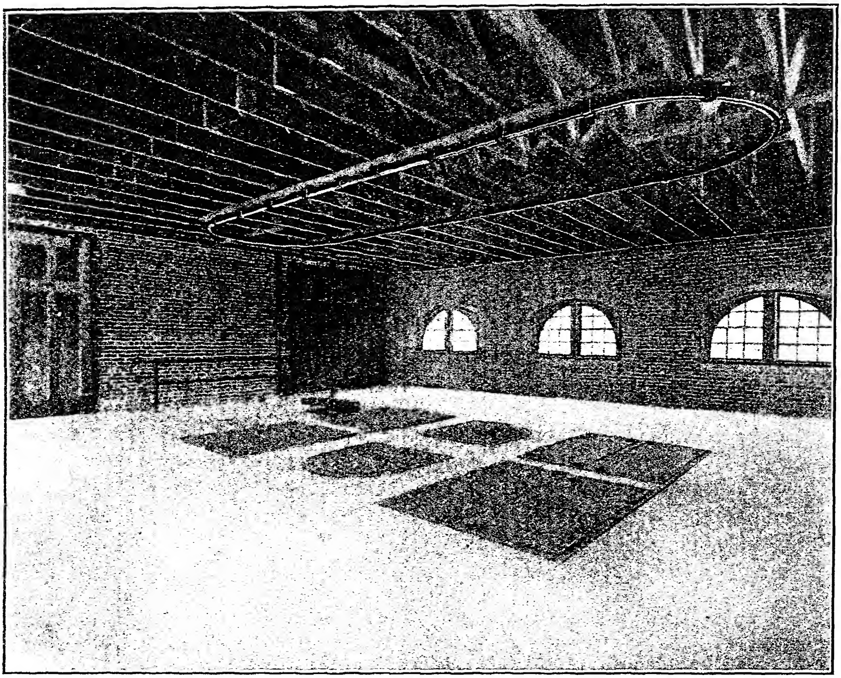

Fig. 88.—Topeka (Kansas, U.S.A.) Crematory. Tipping floor.

No data is yet available as to the operating cost of the crematory at Topeka. Embodying some unusual features in design, its record will be watched with much interest.

Fig. 87 is a view of the crematory and the stoking floor. It will be observed that the furnaces are cased in corrugated steel, which is intended to prevent the infiltration of air through the joints in the brickwork.

The platform on top of the furnaces, as also the covers provided for the feeding hoppers, are illustrated in fig. 88, in which is also shown the trolley truck and chain block, as arranged for the lifting of the feeding-hopper covers.

Portland, Ore.—The incinerator here was erected during 1910 by the Public Works Engineering Company of Portland, Ore., under the patents

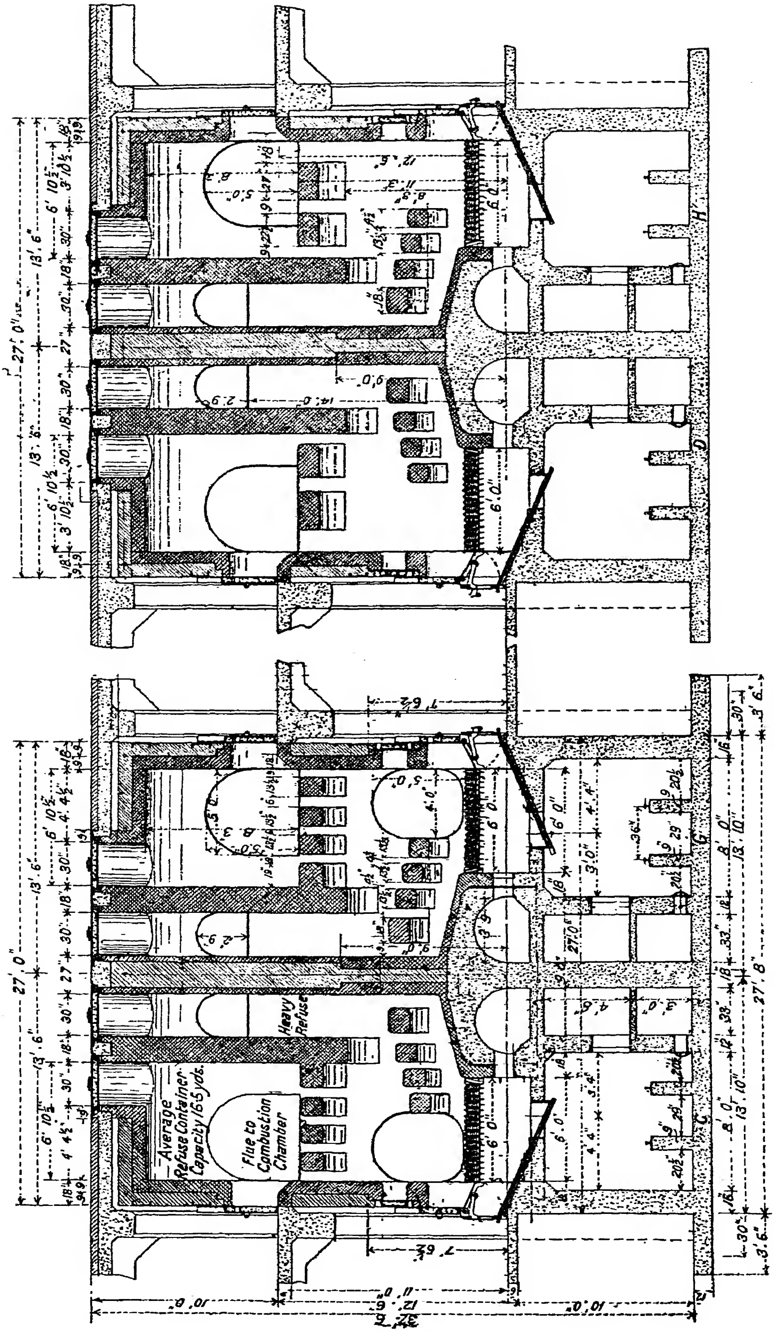

FIG. 89.—The "Fredsmith" Incinerator at Portland (Ore.). Sections.

of Mr Fred. P. Smith, and, as will be observed upon reference to the accompanying sectional illustrations, figs. 89 and 90, in general design it is to a large extent based upon the best British practice.

The plant is arranged in two independent units of four grates each, the total grate area in each unit being 144 sq. ft. Each of the four grates is provided with two ashpits; thus each unit has eight ashpits, and each grate section is 6 ft. long by 3 ft. wide.

While embodying the best features of British designs, the main departure from British practice is found in the provision of refuse containers or drying chambers above the grates, each drying chamber at its base being exposed to the action of the fire beneath.

Four fans are installed, two of which supply air under pressure to the sixteen ashpits in the two units, while the other two fans are for ventilation of the storage bins and building.

The ashpits are arranged for the cooling of clinker by means of the forced-draught air supply; after cooling, the clinker is dropped through a trap-door into a steel car for removal.

Each unit is provided with a Babcock & Wilcox boiler of 100 H.P. capacity, working at 50 pounds pressure; the steam is utilised for heating and for the fan engines.

The works are approached by a reinforced concrete viaduct, 400 ft. long and 18 ft. wide, supported on concrete piers, and the vehicles enter the building through the weighing-room direct on to the dumping floor above the storage hoppers. On the dumping floor are sixteen charging openings, communicating direct with the drying chambers above the grates, four charging openings for boxes and dry refuse, and four charging holes communicating with the storage hoppers on the floor beneath.

The storage hoppers or bins are of concrete construction, with sheet-iron doors, and communicate direct with the furnaces.

The building is of reinforced concrete with brick curtain walls and reinforced concrete floors, the roof being of vitrified tiles carried on steel trusses. The chimney, which is 162 ft. in height, is built of radial blocks and lined with firebricks.

The operating cost of the plant per ton of refuse destroyed over a period of six months is given as follows:—

50 to 65 tons daily	$0.60 per ton.
65 „ 80 „ „	.55 „ „
80 „ 90 „ „	.52 „ „
95 „ 100 „ „	.48 „ „
110 „ 125 „ „	.50 „ „
125 „ 150 „ „	.52 „ „

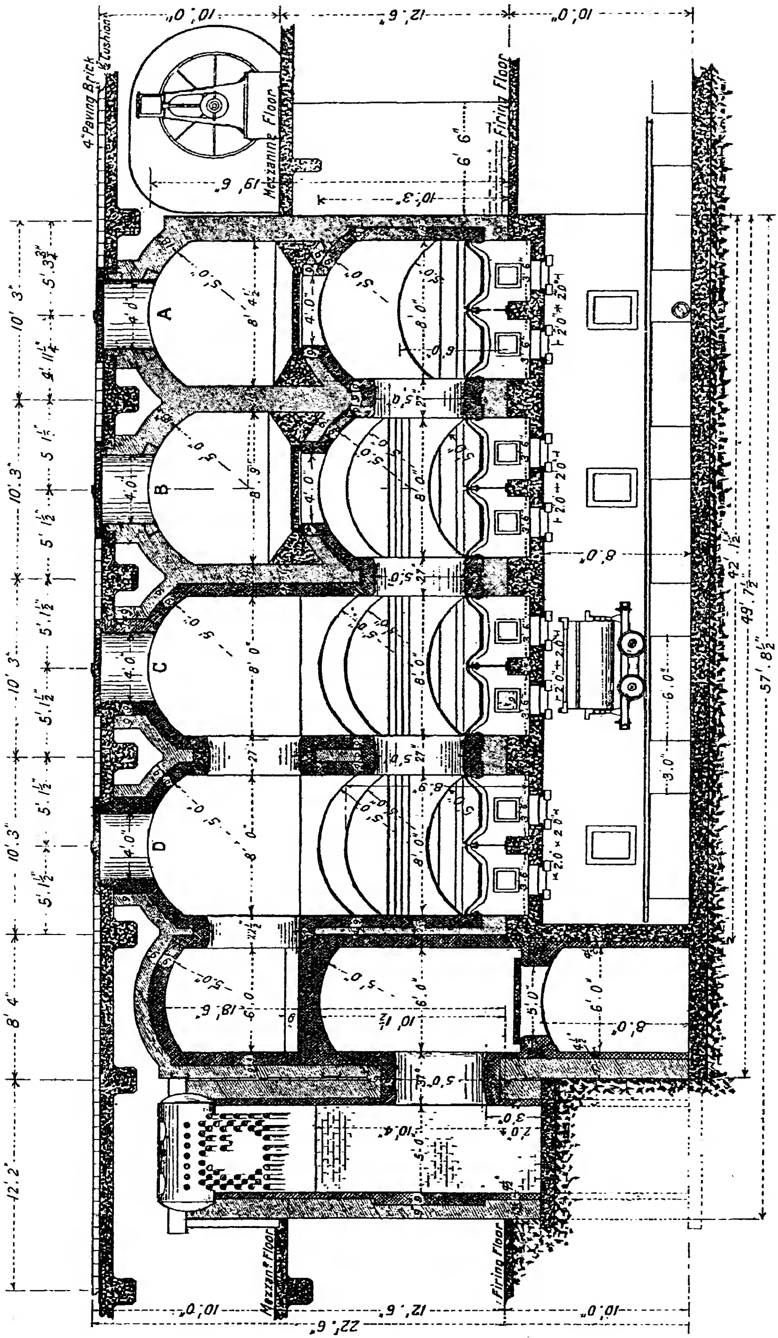

FIG. 90.—The "Fredsmith" Incinerator at Portland (Ore.). Sections.

The following figures refer to a test made on January 23, 1911.

Refuse Destroyed.

Manure	58,645 pounds.
Garbage	146,965 „
Boxes and Paper	15,330 „
One horse	1,290 „

Details of Operating Cost.

7 men at $3	$21.00
2 „ at $4	8.00
$3\frac{3}{4}$ tons coal at $6.25	23.44
$1\frac{1}{2}$ cords green slab wood at $3.00	4.50
Total	$56.94

On the above basis the cost per ton to destroy $110\frac{1}{2}$ tons was $50\frac{1}{2}$ cents.

The Decarie Manufacturing Company have erected a number of garbage crematories, all of which are steel-cased and water-jacketed, although differing somewhat in detail and construction. The grates are made up of steel pipes with headers, and a constant circulation of water is maintained. The grates are arranged in basket form on either side of the incinerator, which is charged from the top; a very considerable number of stoking and inspection holes are provided on all four sides of the incinerator. It is said that an incinerator and fume cremator of 50 tons daily capacity has no less than 40 doors or openings.

The conditions presented for combustion in connection with this crematory cannot be regarded as satisfactory: the burning of garbage in a furnace presenting such a large area of cooling surface presents difficulties which it is idle to minimise or endeavour to explain away.

The author inspected the Decarie crematory at Minneapolis, Minn., early in 1911, and there found just those conditions which one would anticipate: quantities of garbage were being charged in at the top of the furnace, while an examination of the interior through the stoking and inspection doors failed to reveal any evidence of a temperature of even 800° Fahr. at any point, while dense volumes of heavy gases were being discharged from the chimney.

On a horizontal grate, beneath the water-circulating grates, small coal was being burned, but no information was available as to the weight of fuel burned daily. This fuel, owing to the location of the grate, was being burned under very unsatisfactory conditions.

It was said that 300 H.P. per hour was available from the crematory, but the plant which the author saw at the works would not exceed

50 H.P. in the aggregate, including two small generating sets, and a horizontal engine used for driving an induced-draught fan.

According to the report of the garbage department for the year 1909, 19,876 tons of garbage were collected, while the *net* operating cost of the incinerator, after deducting a revenue of $5973.79 for current, and steam supplied for heating, was $16,315.17, or just over 82 cents per ton of garbage destroyed.

The accompanying report of the garbage department gives some interesting details, although the costs per ton for labour and coal, figures of vital importance, are omitted. The average weight of garbage dealt with daily is about 66 tons.

TABLE XXXVI.—CITY OF MINNEAPOLIS, MINN.

Report of Garbage Department, 1909.

1909.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Number of tons of garbage collected	1500	1208	1372	1434	1396	1834	2054	2236	2132	1784	1556	1370	19,876
Number of tons of ashes collected	1510	1346	1430	1338	946	94	184	58	40	954	1548	2368	11,816
Number of dead horses removed	42	56	...	...	3	1	114	46	37	42	34	48	423
Number of dead cows removed	2	2	...	1	1	1	7	4	4	1	1	2	26
Number of dogs removed	...	...	...	...	..	32	117	48	2	19	...	20	298
Number of other animals removed	33	4	36	38	3	4	...	18	32	1	28	1	199

Collection of garbage per capita	132 pounds
Collection of ashes per capita	78 ,,
Total collection garbage and ashes per capita	210 ,,
Cost per capita to collect garbage and ashes	$·12$\frac{5}{8}$
Cost per capita to dispose of garbage	$·07
Cost per capita to collect and dispose of garbage and ashes	$·19$\frac{5}{8}$
Cost per ton to collect garbage and ashes	$·21

At Minneapolis two separate crematories are installed, arranged end to end, while between the two furnaces a Wicks water-tube boiler is set; the gases enter the boiler settings at both sides, while a coal-firing grate is also provided at the front of the boiler. The two crematories are provided with bye-pass flues, so that the gases may travel direct to the chimney when so desired.

In September 1908 Colonel W. F. Morse compiled a chronological list of American furnaces erected from 1885 up to that time, which shows that out of 180 furnaces erected during this period of twenty-three years, no less than 102 had been dismantled or abandoned.

There could perhaps be no more conclusive evidence as to the inefficiency of American furnaces than this record.

For purposes of comparison it may be observed that since 1876, when the first destructor cells were erected in Manchester (England) up to this

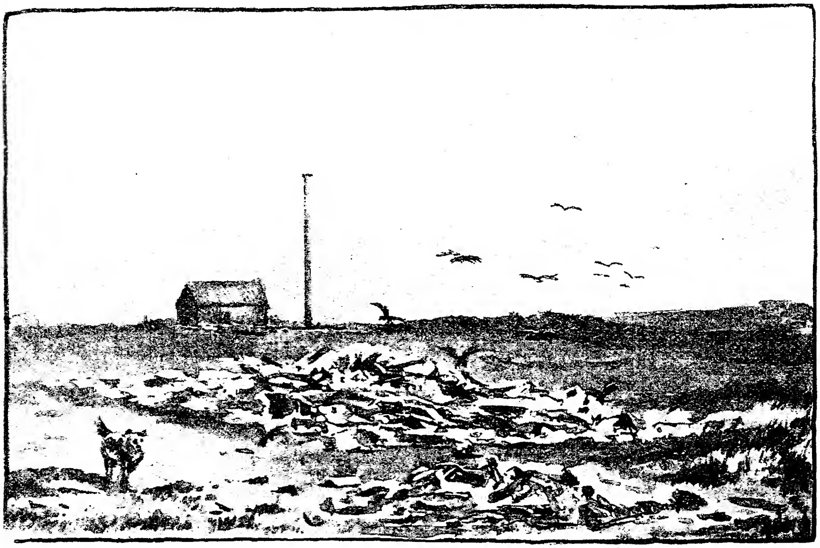

FIG. 91.—An abandoned Garbage Crematory in the Southern States.

time, less than one dozen furnaces have been abandoned, and in nearly every case these have been replaced by up-to-date destructors.

Fig. 91 is a view of an abandoned American crematory in one of the Southern States.

THE REDUCTION OF GARBAGE.

On the whole, the history of garbage destruction in the United States is no more satisfactory than is the history of crematories and incinerators. Introduced in 1886 from Vienna by Mr H. A. Fleischman, reduction works have been erected in or near to many large cities, in almost every case by a company who have contracted with the municipality to take the garbage for a term of years with an annual subsidy.

According to statistics collected by Colonel W. F. Morse, some forty-five reduction works had been erected, or were in course of erection, up to September 1908, covering a period of twenty-two years. Out of this number nearly one-half were no longer in use at that time.

Mr H. de B. Parsons, in a paper read before the Society of Chemical Industry, New York, in March 1908, thus sets forth the advantages and disadvantages of reduction:—

"Advantages.

"1. The organic or putrescible matter in the garbage is converted into grease and tankage, which are harmless.

"2. It saves components which have a commercial value.

"3. With a properly designed and carefully worked plant the process need not be a nuisance.

"Disadvantages.

"1. Expensive machinery and apparatus, with large costs for renewals and repairs.

"2. The offensive odours which are apt to be given off require expense to prevent an annoyance.

"3. As the works have to be situated some distance from the city, haulage is an important factor.

"4. Skilled labour is required, and there is some danger from strikes.

"5. The garbage must be separately collected. There will always be some foreign material, tin cans and the like, which require to be sorted out at the works.

"6. There is usually but one plant, as a number of small plants would not pay. The whole system, therefore, would be crippled by fire, or by any other cause that would stop the plant.

"7. The process provides for the garbage only, leaving the remaining refuse to be treated otherwise."

The best known reduction systems are the Arnold, using live steam for cooking, and the Merz and Simonin processes, in connection with which a solvent such as naphtha or benzine is used.

The recovered grease averages about 3 per cent., or 60 pounds per ton of garbage, and finds a ready market at a price varying from 2 to 4½ cents per pound; hence the value of the grease and oil per ton of garbage treated will vary from $1.50 to $2.40. The crude material is refined by the purchasers, its chief constituents being glycerine, stearine, and red oil.

The tankage or solid fibrous residual, averaging about 9 per cent. by weight when dried and ground, is dark brown in colour, and should be

practically odourless. This, which is said to sell freely, is used as a base for commercial fertilisers; the price, which is variable, is based upon the "units" of ammonia contained.

It is useless to disguise the fact that the process of reduction is a paying process; and for dealing with large quantities of garbage alone, there is no process yet devised which is capable of yielding anything like the same revenue.

At the same time it must be borne in mind that the cost of the necessary plant is so heavy as to restrict the use of the system to the larger cities and towns. It is open to serious question whether a profit can be shown on less than 80 tons of garbage daily.

The record of garbage reduction in the United States would have been far more satisfactory had it not been regarded mainly as a business venture, promising a handsome return on capital invested.

When contracts are made for periods of five or ten years it is perfectly obvious that the only sound business policy for any reduction company is to ensure, as far as possible, that the capital expended shall be recouped with a reasonable profit.

Under such circumstances a reduction company go into business without any regard for a sanitary ideal; they are merely concerned with the problem of making the business pay; hence it is that capital expenditure is cut down to the minimum, and that improvements, having for their object the prevention of nuisance, are not adopted. Everything is sacrificed in the determination to make large profits, and to make them quickly.

The largest garbage reduction works in the United States is at Barren Island, and is owned by the New York Sanitary Utilisation Company. At these works, during the year 1909, 332,045 loads of New York and Brooklyn garbage were treated. Having been towed to the Barren Island works, the garbage is forked on to an outboard conveyor, and is then conveyed to the second story of the works and passes through shoots to the digesters. Its reduction is then accomplished by the Arnold Egerton process, which is performed by mechanical means. The digesters are large tanks, holding approximately 8 tons. When filled, they are sealed by a cap held in position by bolts. Steam is introduced into the digesters at 80 pounds pressure, and the mass is cooked for a period which is determined by its composition, which varies from season to season. The vapour escaping through the vent is condensed by a jet condenser, and thence passes to a sewer.

From the digester the material, which is now a pulpy mass, is removed to a tank, which has a capacity equal to that of four digesters, for the

purpose of facilitating the work. From these tanks it is run into forms made of sacking and racks, and there put under a hydraulic press; pressure is then applied, and the water and grease are thus removed.

The water and grease next pass into a perforated trough, and thence by pipes to a settling basin, where by flotation the grease is separated, and then removed and barrelled. The residue from the hydraulic press, which is known as tankage, is carried by a conveyor to a direct heat dryer, where the remaining moisture is driven off, and from the dryer passes on to a screen, where the material is ground and screened. From this screen the material falls through shoots into hoppers, and is then put into sacks ready for shipment.

The average New York and Brooklyn garbage, as received at the Barren Island works, contains—water 71 per cent., rubbish 6 per cent., tankage 20 per cent., and grease 3 per cent. The grease is of a low grade, dark brown in colour, and is largely used in the manufacture of soap and candles, the greater portion being shipped abroad. The tankage, which is sold as a fertiliser base, contains small percentages of nitrogen, ammonia, phosphoric acid, and potash. The residual liquor from the grease basins is of no value, containing but a very small percentage of ammonia.

That the garbage of New York is of considerable value to the Sanitary Utilisation Company will be clear from the following estimate[1] of receipts and expenditure during the year 1908:—

Receipts.

Grease, 3 per cent. of total garbage, 9859 tons, at $60 .	$591,540
Tankage, used for fertiliser, 65,729 tons at $5 . .	328,646
Cash from Department of Street Cleaning . . .	192,444
Total Receipts .	$1,112,630

Disbursements.

Transportation from docks to works, by scows, 328,646 tons, at 12c. per ton	$39,437.52
Unloading, 5c. per ton	16,432.30
Coal, 22c. per ton of green garbage reduced . .	72,800.00
Labour, 14c. per ton	46,800.00
Repairs and supplies, 5 per cent.	50,000.00
Depreciation, 10 per cent.	100,000.00
Administration and legal expenses	225,500.00
Balance, gross profit	561,660.18
Total .	$1,112,630.00

[1] From *The Municipal Journal and Engineer*, New York.

The capital stock of the company is $1,300,000; for a 6 per cent. dividend $78,000 would be required. The sum of $192,444 paid by the Department of Street Cleaning is also included in the gross profit as stated above. The net value of the garbage delivered at the docks in 1908 was thus $369,216, or, if dividends are deducted, $291,216.

In order to fully understand these figures, some further information regarding the items follows:—

Tons.—A cartload is assumed to weigh 1 ton. This estimate was confirmed by exhaustive tests made by Messrs Parsons, Hering, and Whinery in connection with a report to the board of Aldermen, dated December 31, 1907. The number of cartloads delivered by the city at the docks to the company in 1908 was 328,646.

Grease and Tankage.—The percentage of grease recovered from New York garbage by the process employed has been reported to be 3 per cent. The average price for grease in 1908 was $60 per ton. The tankage, which is used for manufacturing fertilisers, has been stated to be 20 per cent., and its value is put at $5 per ton.

Transportation.—The estimate of 12 cents per ton for transportation by scows is based on the city's contract for disposing of ashes and rubbish in a somewhat similar manner. The price which it pays for this is 17 cents for transporting and unloading, but the nature of the work is considerably more expensive than that involved in the handling of garbage. The following estimate of cost of unloading alone is submitted. The average scow carries 300 tons. Ten men at $1.50 per day easily unload one scow in a day, making the cost 5 cents per ton.

Coal.—The total annual consumption of coal at the reduction plant is reported to be 18,200 tons, estimated to cost $4 per ton, or $72,800 = 22 cents per ton of garbage.

Labour.—The estimate of labour is obtained from observation. The average number of men employed is about 70. The average weekly pay roll is $900; the annual pay roll $46,800, making the labour cost per ton of green garbage handled 14 cents.

Repairs and Supplies.—The figure of $50,000 is assumed arbitrarily.

Depreciation.—The value of the plant is assumed to be within $300,000 of the capitalisation of the company, and 10 per cent. is allowed for depreciation, permitting renewal every ten years. The allowance for depreciation is $100,000.

Administration and Legal Expenses.—These are assumed to be $225,000.

Interest or Dividend.—This is figured at 6 per cent. on the capitalisation of $1,300,000. The profits over and above the amount

paid by the city appear to be $29,121,618, or 22 per cent. on the capital stock.

Regarding the cost to the city of collecting the garbage and delivering it to the company at the docks, the following figures are reported for 1908:—

Boroughs.	Cartloads	Cost per Load.
Manhattan	195,439	$1.32
Brooklyn	27,839	1.43
Bronx	105,368	1.18
	328,646	

The sums paid by each borough to the company under the terms of the contract for disposing of the garbage after delivery are as follows:—

Manhattan	$148,000
Brooklyn	19,444
Bronx	25,000
	$192,444

There are signs that garbage reduction will be undertaken by municipal authorities to some considerable extent within the next few years. Up to the present time two cities only are operating reduction plants, and in both cases the results obtained are such as to encourage the hope that this work will, in the near future, be taken in hand by the municipalities in their capacity as sanitary authorities.

The first city to operate a reduction works was the city of Cleveland, Ohio. Prior to 1905 the garbage of this city was removed under a private contract with the Newburgh Reduction Company, at a cost to the city of $69,400 per year. On January 1, 1905, the city purchased the reduction works and collection equipment from the Newburgh Company for $87,500, and without any loss of time attention was directed to the extension and improvement of the works, which, in spite of considerable capital expenditure, are an established success, showing a small net profit after meeting all capital and standing charges.

Encouraged by the results obtained at Cleveland, and failing to obtain satisfactory bids for the disposal of their garbage, the city of Columbus, Ohio,—one of the most progressive municipalities in the United States,—decided to design and erect a reduction plant. By the courtesy of Mr Irwin S. Osborn, Engineer in charge of refuse disposal for the city of Columbus, the author was privileged to inspect the reduction works in this city early in 1911. Mr Osborn, who was responsible for the design and equipment of the works, and who now

superintends the operation of the same, has kindly furnished the following very complete description:—

"On July 20, 1910, the city of Columbus, Ohio, started the operation of the first reduction plant designed and constructed by a municipality for the disposal of garbage. The majority of the larger cities in the United States dispose of their garbage by the reduction process under contract with private companies. The only other garbage reduction plant owned and operated by a municipality was purchased by the city of Cleveland, Ohio, in 1905, from the Newburgh Reduction Company, which formerly had disposed of the city's garbage by contract.

"The reduction of garbage has, in most cases, proved successful when considered from a commercial standpoint, although failures in this method of disposal have occurred as well as in other methods of disposal, due usually to faulty design, or the lack of proper attention and management. From a sanitary standpoint the reduction of garbage has been looked upon as being very undesirable, due largely to the manner in which the plants have been constructed and operated. This will continue to be the case so long as cities contract for the disposal for a short term of years. The contractor cannot then afford to install a plant except at a small first cost, with little attention being paid to the design from a sanitary standpoint. Under contract, the work is considered chiefly from a commercial standpoint, which consists in obtaining the largest remuneration possible at the least cost.

"Previous to April 1906 the city of Columbus contracted for the collection and disposal of garbage. The contract has proved very unsatisfactory in regard to the poor collection service, and the nuisance caused by the odours from the reduction plant. The plant was one of the early types, and constructed at a small first cost, with little regard for the sanitary features, because the small amount paid the contractor was not sufficient to even pay for the cost of collection. At the expiration of the contract in April 1906 the city installed a municipal collection system and disposed of the garbage by burying it on what is known as the English farm. This was owned by the city, and is located about one mile southwest of the city limits.

"After making an extensive study of the garbage problem of the city, at the expiration of the contract, bonds were issued amounting to $290,000 to cover the cost of a disposal plant and new collection equipment. The first plan was to contract for a crematory and dispose of all garbage and refuse by incineration. Before the plan was carried out a change of administration took place, and the newly elected officials decided to contract for a complete reduction plant, so as to obtain bye-

products from the garbage which would yield returns that could be applied to the cost of disposal. After advertising twice without receiv-

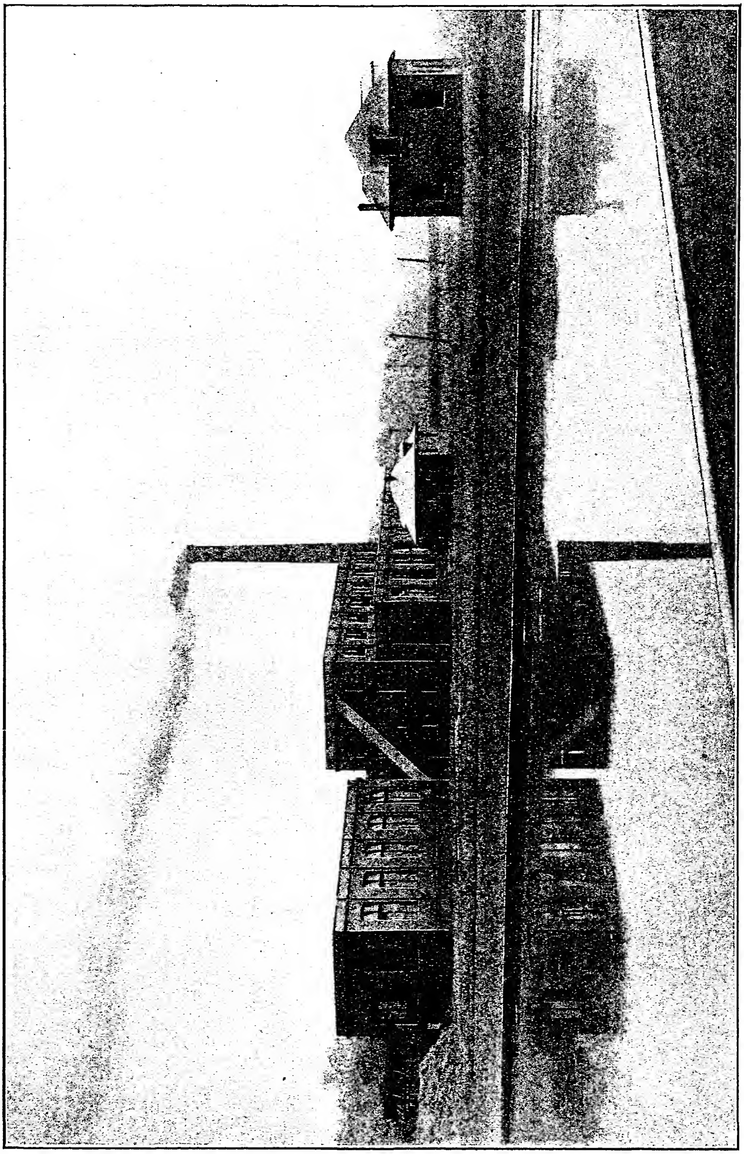

FIG. 92.—City of Columbus (Ohio) Garbage Reduction Works, view of buildings and chimney.

ing satisfactory bids, the city decided to design the plant and contract for the several parts separately. By this plan they were able to accept

such machinery and equipment as had proved most satisfactory, and at the same time not be dependent on any one particular patented process.

"In designing the Columbus plant, the first object was to make it as sanitary and free from undesirable features as possible, and at the same time make the appearance of the buildings and general design agree favourably with other municipal improvements. The plant was designed with a capacity for disposing of 80 tons of garbage in twelve hours, or a total capacity of 160 tons per day with the plant operating continuously.

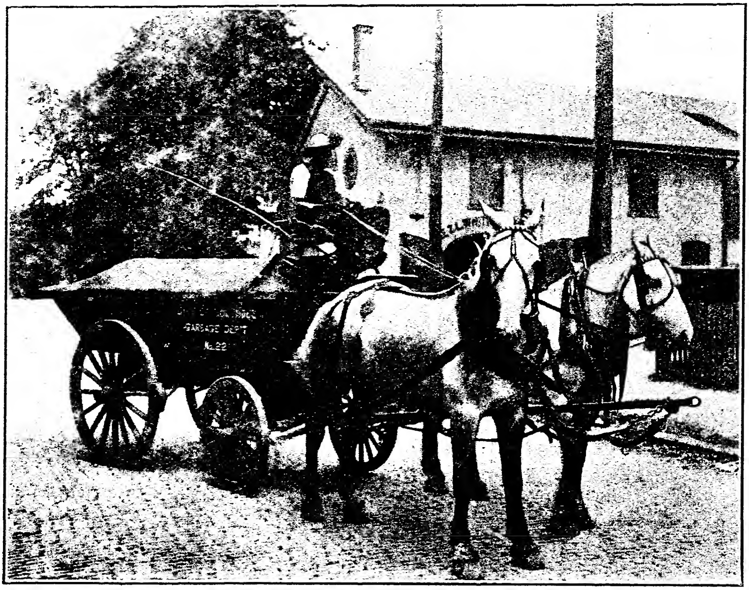

FIG. 93.—Garbage Collection Wagon, City of Columbus (Ohio).

The total capacity of the plant is sufficient to take care of the future growth of the city for twenty years. The capacity is about double the amount of garbage being collected at the present time, so that as the city grows the plant will be operated with a larger staff and more hours per day.

"The garbage is collected in wagons which have water-tight steel bodies and sectional canvas covers. The garbage is hauled to a central loading station located on the Hocking Valley Railroad near Mound Street. The loading station consists of a building 40 ft. wide by 90 ft. long, with a railway track extending through the building. There is room for two garbage cars inside the building when the large track doors are closed.

"The cars are constructed with semicircular bodies especially for handling garbage. The body is on trunnions, so as to allow it to be turned when unloading. The cars are four in number and have a capacity of 1400 cubic ft. or 40 tons each. Two cars are at the loading station while the other two are at the reduction plant.

"The wagons are drawn up an inclined driveway on to the second floor of the loading station, and by means of a power hoist the front end

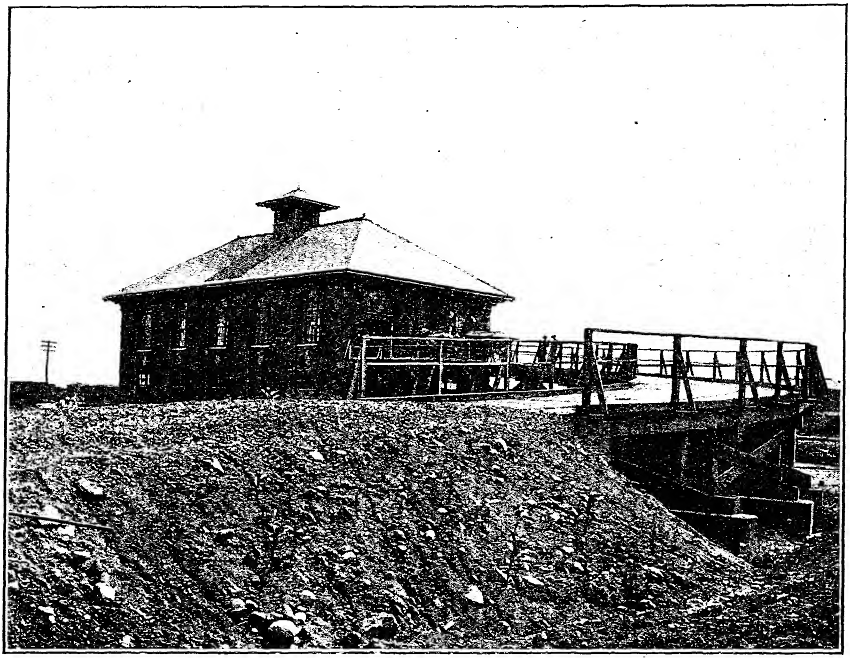

FIG. 94.—City of Columbus (Ohio) Garbage Loading Station.

of the wagon body is elevated, discharging the garbage out at the rear end into the garbage cars below. All work at the loading station is carried on inside the building, so as not to cause any complaint from the surrounding community on account of unsightly appearance or odours. The collection wagons are 34 in number, with an average of 25 in regular service. Adjoining the loading station are the stables for the collection department, which have a capacity for stabling 100 horses. The offices of the collection department, and lockers and bathrooms for the men, have been placed on the second floor of the stable.

"Between seven and eight o'clock each evening the day's collection is

delivered at the reduction plant by the Hocking Valley Railroad Company, and the empty cars, after being thoroughly cleaned, are returned to the loading station.

"The reduction plant is located about four miles south of the centre of the city, on the Scioto river, and near the sewage purification works. The railroad tracks at the plant are on top of the levee which surrounds the building site, and about 10 ft. above the ground-level of the buildings.

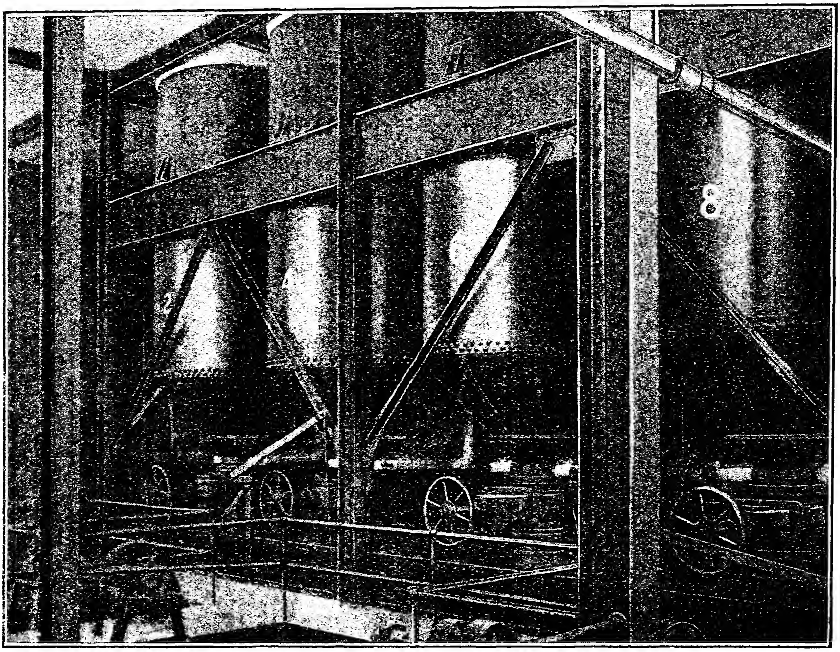

FIG. 95.—City of Columbus (Ohio) Garbage Reduction Works, view of Digesters—capacity 10 to 11 tons each.

This elevation allows all material coming to the plant to be discharged from the cars by gravity. The coal is discharged from side or bottom dump cars into a storage bin in front of the boilers.

"At the plant there are four buildings: the main building, which is 162 ft. long by 76 ft. wide, the green garbage building, 90 ft. long by 40 ft. wide, a small office building, and a stable. The garbage when delivered at the plant is weighed on railway track scales, and then run into the green garbage building on a siding which extends through it. The body of the car is then turned on trunnions by means of power hoists and the contents of the car discharged on to the floor below. The

free water is drained off through a gutter extending the full length of the building and covered with perforated plates. The swill water from the gutter is drained into a catch basin, from which it is discharged into

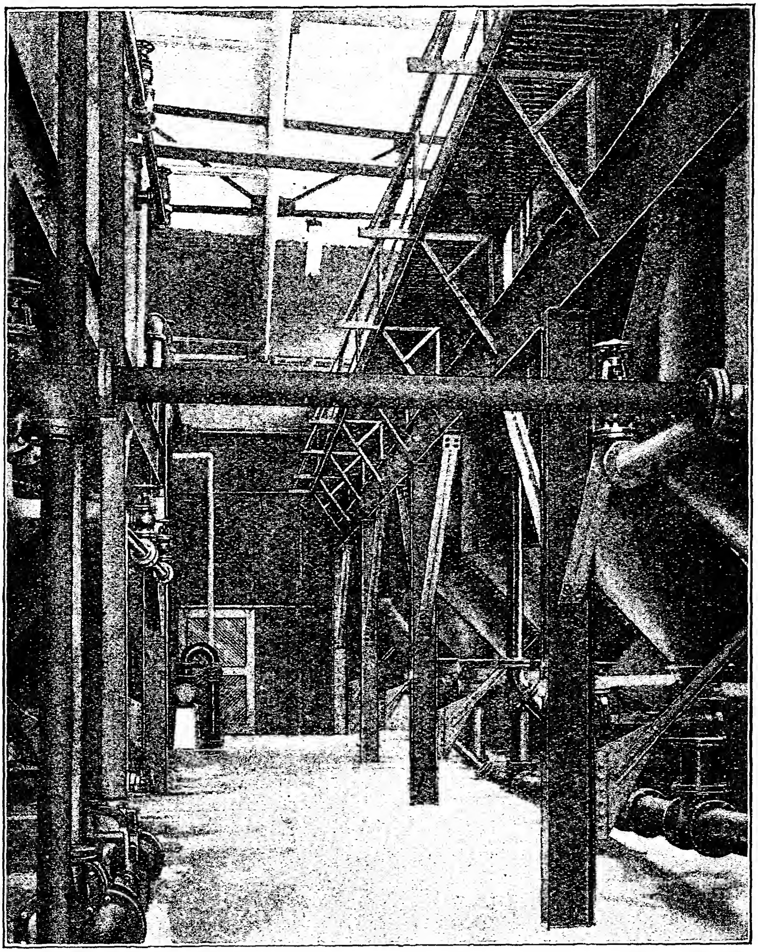

FIG. 96.—City of Columbus (Ohio) Garbage Reduction Works. Grease-separating room.

the grease-separating tanks, after which it is evaporated. The garbage is sorted and shovelled into a 24-in. scraper conveyor which extends the full length of the green garbage building. Connecting this building with the main building is an incline truss which carries the conveyor to the top of the main building, and then along the bottom cord of the roof

trusses and over the tops of the digesters. Connecting the conveyor with the digesters are swivel spouts which discharge the garbage directly into the digesters.

"The digesters are eight in number. Each digester is 7 ft. in diameter by 14 ft. long, constructed of flanged steel $\frac{5}{8}$ in. in thickness, and having a capacity of 10 to 12 tons of garbage. The inside is lined with cement and tile $1\frac{1}{2}$ in. thick, so as to protect the digester from wear, due to the

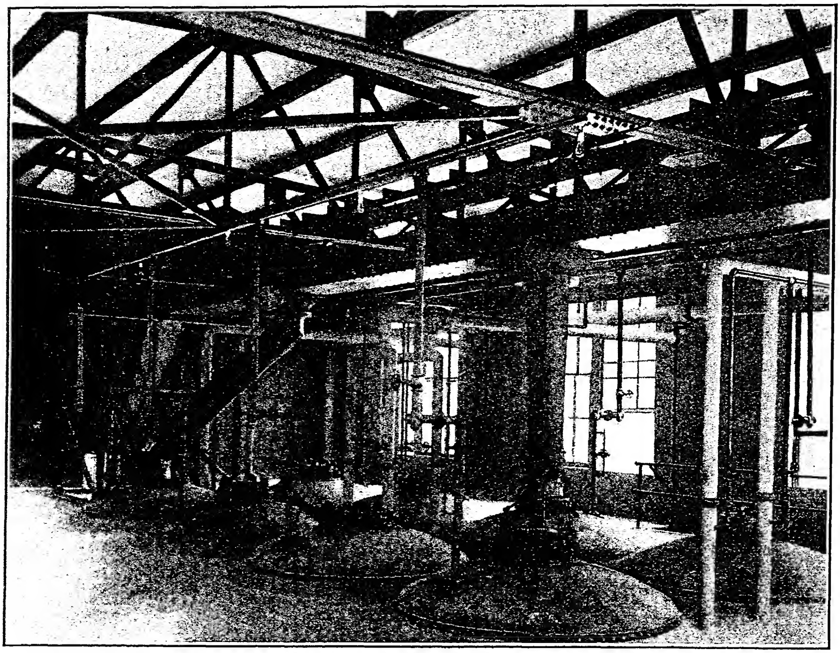

FIG. 97.—City of Columbus (Ohio) Garbage Reduction Works, view of Digester floor, showing charging spout.

agitating of the gritty material when boiling, and at the same time to resist the action of the acid which would attack the metal. At the top of each digester is an 18-in. diameter cast-iron inlet door and frame, and on the bottom is a 16-in. flanged outlet for attaching the discharge valve. The outlet castings are tapped on the opposite sides for pipe connections through which live steam is admitted for cooking. The steam is turned into both connections at the same time; and as the discharge from the steam nozzles comes together, the steam spreads and circulates through the mass. The top of each digester is connected by a brass vent pipe to a condenser. When cooking, the steam is allowed to escape through a

$\frac{1}{4}$-in. bye-pass so as to ensure against the digester becoming air-bound, and thus prevent the steam from entering. The digesters are arranged in nests of four, and are connected to a common receiving hopper by a large gate valve and nozzle on the bottom of each digester. When cooked, the garbage is discharged through the large valve into the receiving hopper, which is directly connected to the roller press. The four digesters, one receiving hopper, and a roller press are called one unit.

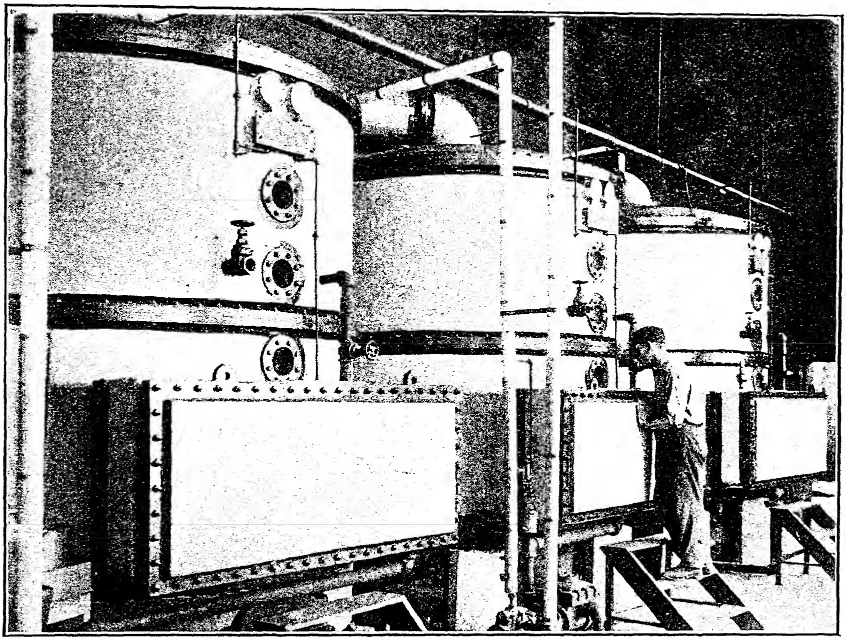

FIG. 98.—City of Columbus (Ohio) Garbage Reduction Works, view of triple-effect Evaporators.

"The vapours which arise from the mass when dropped into the receiving hopper are conducted by a vent line to a condenser, which, with the condensers for the digesters, is connected to a vapour-tight steel hot well. Any odours that are carried by the gases and not taken up in the condensers are trapped in the hot well and then passed by a vent line to the boiler furnaces.

"The time required in cooking varies with the quality of garbage, but averages about 6 hours with the steam, at from 60 to 70 lbs. gauge pressure as it enters the digester.

"The presses, which are connected to the receiving hopper, are of the continuous-roller type, and were designed by Mr Charles Edgerton

especially for handling garbage. They are constructed throughout of cast iron, wrought steel, and cast steel, with renewable wearing strips, take-up boxes, and cleaning brushes. Each press is enclosed in a vapour-tight cast-iron housing, approximately 28 ft. long, 3 ft. wide, and 7 ft. high. The presses are directly connected to the bottom of the receiving hoppers, so that the material from digesters passes through the press before being exposed. The press is provided with an upper and lower

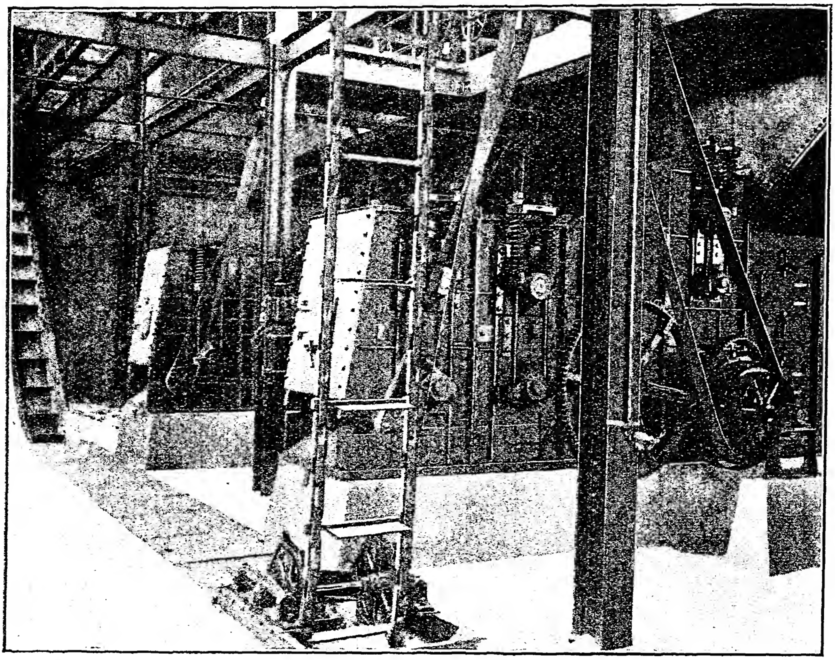

FIG. 99.—City of Columbus (Ohio) Garbage Reduction Works, view of Roller Presses.

conveying apron. The upper apron is made up of $\frac{1}{2}$-in. steel slats riveted to a heavy forged steel chain. The upper apron acts as the bottom of the receiving hopper, and when the press is running carries the material through the feeding rolls and discharges it on to the lower apron. The lower apron is composed of perforated slats $\frac{3}{8}$ in. in thickness, riveted to a forged steel chain of the same character as that used in the upper apron. The lower apron passes through between six cast-iron rolls, arranged in pairs. The rolls are 28 in. in diameter and are controlled by heavy steel springs so that they may be regulated to any desired pressure, depending on the quantity of material to be passed through.

"The pressed material is discharged at the front of the press into a scraper conveyor, which carries it to the second floor of the drying department. The press is driven by a belt from a counter-shaft, which in turn is driven by a $7\frac{1}{2}$ H.P. motor, directly connected by spur gear. The pressing rolls are driven by chains, and the press constructed so that one apron or both can be operated at the same time. On the feeding roll is a safety device to protect the press should any foreign substance get at the back of the roll which is too large to pass through or too hard to be crushed by the rolls. The press can be reversed so as to remove any material if desired from under the rolls.

"The water and grease flow back from the press through a covered conduit to the catch-basins in the grease-separating room. The catch-basins are below the floor, and in the bottom of each is a small centrifugal pump, which is driven by a vertical motor. The water and grease are pumped from the settling basins into a battery of tanks, where the grease is separated by gravity. The separating tanks are six in number, and connected in series by an 8-in. by 12-in. opening near the top. The grease rising in the first tank overflows into the second, and from the second to the third, and so on through all the tanks, with the largest amount of grease collected in the sixth tank, from which it is drawn off by means of a pipe line into one of two treating tanks. Each tank is 7 ft. in diameter and 12 ft. long, and constructed with a flat top and cone bottom.

"The grease drawn off from the separating tanks is heated up in the treating tanks in order to separate the impurities, and then pumped into storage tanks ready for shipment. The grease storage tanks are four in number, with a total capacity for storing 15,000 gallons of grease. The storage tanks are so piped that the grease can be pumped into any one of the tanks, or be drawn off and discharged into railway tank-cars for transport.

"The liquor as it comes from the presses carries more or less solids in suspension. These solids are known as muck and silt. The muck settles at the bottom of the tank, and the silt rises to the top of the water just below the grease. By means of a pipe connection the muck and silt are drawn off by a magna pump and discharged into a muck tank, which is similar in design to the separating tanks. The solids from the muck tank are placed in a screw press, from which the liquor flows to the catch-basins and the solids are placed in the conveyor leading to the drying-room.

"The tank water, after the grease has been separated, is drawn off into a large storage tank outside the building. The first and sixth separating

tanks are provided with a large control valve, so that the liquor can be raised or lowered to any desired height in the tanks. The tank water from the last separating tank is drawn off about 4 ft. from the top, and so piped as to trap the grease. This allows the liquor to be pumped into the tanks continuously, with only the tank water flowing to the storage tank, leaving the grease to be drawn off as desired into the treating tanks.

"The tank water from the storage tank goes to a triple-effect evaporator, so as to recover the 5 to 7 per cent. of solids in solution. The evaporator is made up of three round-bodied cast-iron pans, 8 ft. in diameter, and built especially for the conditions to be met in handling garbage tank water. All the parts that come in contact with the liquor are made extra heavy, and the third pan is made with a special bottom for removing the solids that accumulate. Ths total heating surface in the three pans is 2554 sq. ft., made up of No. 14 old-gauge brass tube $1\frac{1}{4}$ in. in diameter. The tubes are placed horizontally, and secured in position by means of gaskets and packing rings.

"The evaporator is capable of concentrating 1500 gallons of tank water per hour from 7° to 22° Beaume, using exhaust steam at 5 lbs. pressure and a vacuum of 25 in. on the third pan. By use of the round bodies all internal bracing is discarded and the pans constructed with fewer joints. Each effect is equipped with an internal separator to prevent entrainment, manhole, vacuum breaker, vent pipe, four peep holes, internal electric light, and the necessary gauges. The condensation is handled by condensation pumps, and the concentrated syrup is drawn off by a magna pump and discharged into a storage tank on the second floor of the drying department.

"The feed pump to the evaporator is provided with a neutralising gear and connected to a tank containing a neutralising solution. By means of the neutralising gear the required amount of solution is mixed with the tank water to neutralise the acid, so as to prevent it attacking the metal. The vacuum is maintained by an 8-in. by 12-in. by 12-in. condenser pump of the injection type.

"The solids from the roller presses, after they are delivered to the drying department, are fed into a revolving cylindrical dryer. This dryer is constructed with a steam jacket, and the inner shell is provided with lifting angles in short lengths arranged so as to have free expansion and contraction. The lifting angles carry the material well up on the rising side of the dryer. The heat for drying is obtained from the steam jacket and radiator coils, which are at the discharge end of the dryer. The radiator consists of four sets of coils, which are 5 ft. high by 6 ft.

wide, and made of standard 1-in. pipe. The coils are covered with a housing which is connected to the rear end of the dryer. A small cast-iron blower is connected to the rear of the housing, and when running discharges air through the coils, and then into the shell of the dryer. At the feed end of the dryer is placed another cast-iron blower, which exhausts the saturated air, and discharges it through a condenser tower, and then to the boiler flue. The material to be dried is fed into the dryer continuously, and discharged by means of a short spiral

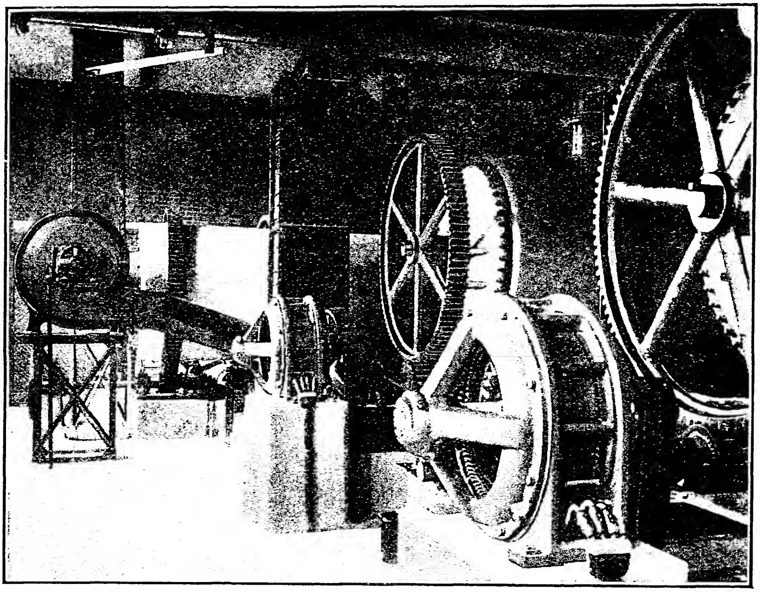

FIG. 100.—City of Columbus (Ohio) Garbage Reduction Works, view of drive end of Dryers.

conveyor at the opposite end. The material is made to pass through the dryer by the inclination at which the cylinder is set. The shell revolves on trunnions, and is driven by a 10-H.P. motor directly connected by spur gearing.

"The dry material from the revolving dryer is elevated to the second floor and passed through a revolving screen. The screened tankage is then placed in the vacuum or mixing dryers, and the concentrated syrup from the evaporator is added. The dry fibrous material acts as a filler, and enables the moisture in syrup to be driven off. The addition of the syrup to the fibrous tankage produces a higher grade of tankage from a mechanical and fertilising standpoint. The vacuum dryers are two in

number, and constructed with a 2-in. steam space between the outer and inner shell. The dryers are 15 ft. long and 60 in. in diameter. Through the centre of each dryer is a shaft to which paddles are attached for agitating and mixing the material. When dry the material is discharged from the dryer into a spiral conveyor connected to an elevator which discharges the tankage on to the third floor, where it is stored until shipment.

"The city now has under construction a percolating plant to be used in the extraction of grease from the dry tankage, as only about one-half of

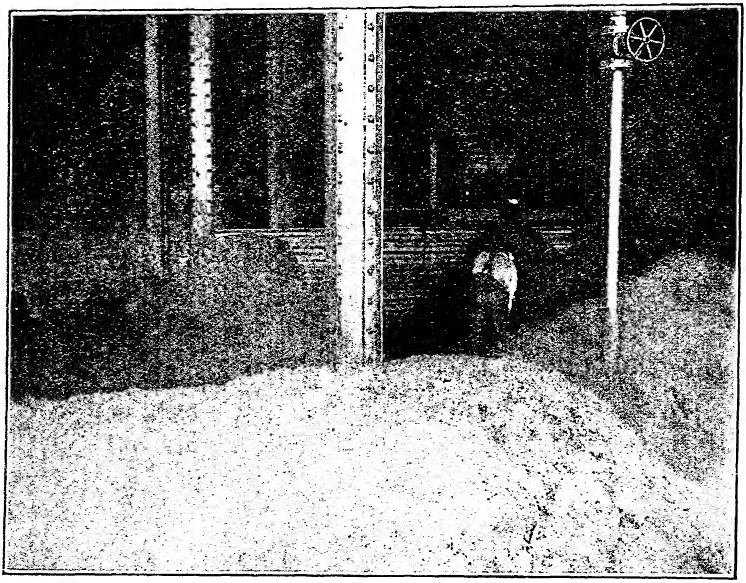

Fig. 101.—City of Columbus (Ohio) Garbage Reduction Works. Tankage.

the available grease is recovered by means of the press. The percolating plant will consist of extractor, vaporisers, condensers, and storage tanks, and will be located in a small building just west of the main building.

"The electric current for both lighting and power is furnished by the municipal light plant at a cost of 1½ cents per kilowatt-hour. An independent motor is connected with each power-driven unit, and operated with 440-volt, 60-cycle, two-phase current. The boiler plant consists of three horizontal tubular boilers 78 in. in diameter by 20 ft. long. Two of the boilers are in regular service and the third is in reserve.

"The buildings are constructed fireproof throughout, having concrete

foundations, steel frame and roof trusses, reinforced concrete floors, brick walls and a hollow terra-cotta roof tile, covered with a built-up four-ply composition felt and asphalt roofing. The exterior and interior walls of the building are laid up with a high grade, impervious, wire-cut face brick. The construction of all parts, so far as possible, was made to agree with the best modern practice employed in building construction.

"The approximate cost of the plant was $180,000, divided up as follows:— Grading and levee, $11,000; buildings, $76,000; garbage machinery, $60,000; power and conveying machinery, $30,000; railway tracks, $3000. The construction of the plant, including the buildings and machinery, was carried on under ten separate contracts. The buildings were built by D. W. M'Grath, of Columbus, Ohio. The power plant equivalent was installed by the Wm. H. Conklin Company, Columbus, Ohio. The digesting, pressing, and grease-separating equipment was furnished by the Kutztown Foundry & Machine Company, of Philadelphia. The conveying machinery was installed by the Jeffrey Manufacturing Company, of

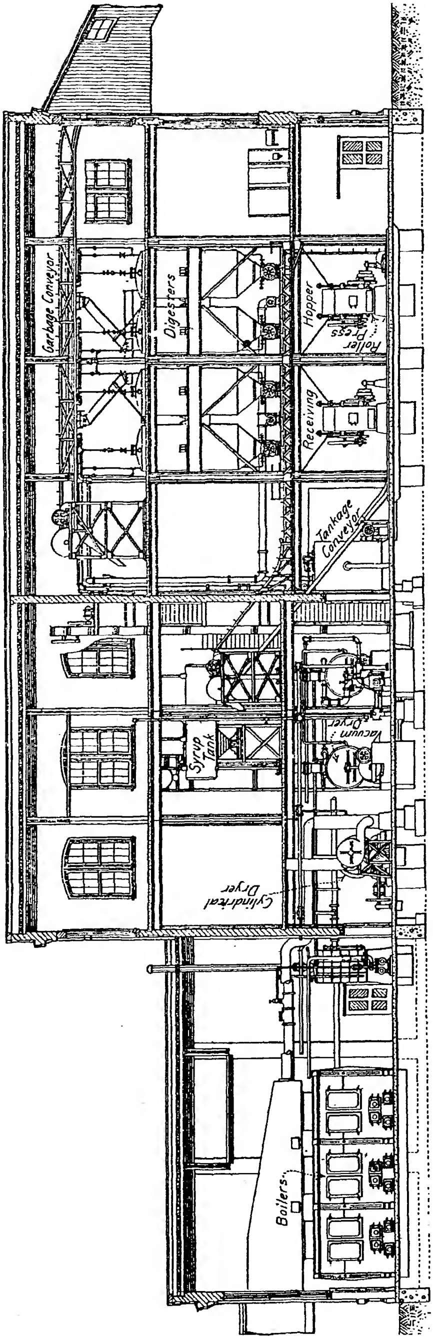

FIG. 102.—City of Columbus (Ohio) Garbage Reduction Works. Longitudinal section.

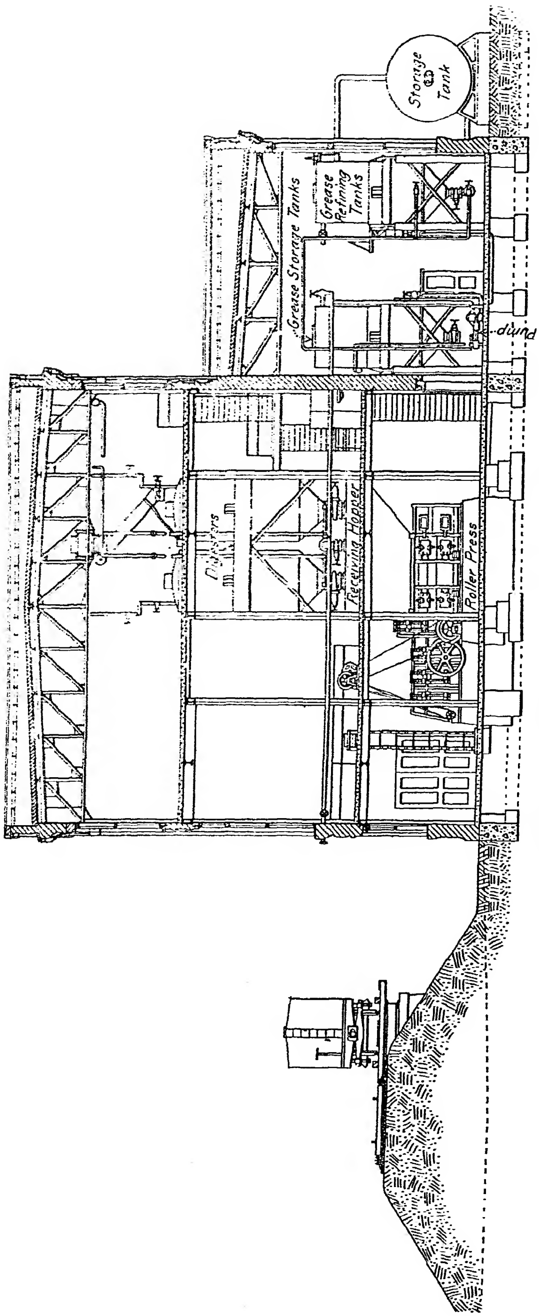

Fig. 103.—City of Columbus (Ohio) Garbage Reduction Works. Section through digester room.

Columbus. The drying machinery was installed by the C. O. Bartlett & Snow Company, Cleveland. The evaporator was supplied by the Zaremba Company, of Buffalo, N.Y.

"The Columbus plant contains very little experimental machinery, although in a number of ways it differs from other reduction plants. The chief difference is in the separation of grease in closed tanks and the condensing and deodorising of the gases. The evaporation of all the tank water in a triple-effect evaporator is entirely new in the disposal of garbage, although used extensively on the tank water in the larger packing-houses. It was not the intention in designing the Columbus plant to try experimental machinery, but rather to assemble machinery of known and tried types to their best advantage, and only such as had proved satisfactory in other

plants. The plant was designed with the idea that by use of the reduction process the garbage could be disposed of at the least cost, and at the same time in a perfectly sanitary manner.

"After three months of operation the plant has more than met all expectations, as the returns from the sale of bye-products have more than paid for the cost of disposal. The actual results obtained we will leave until the plant has been in operation several months, and has had a chance to demonstrate just what can be done in the disposal of garbage by the reduction process." The Columbus reduction plant is fully illustrated in figs. 92 to 107.

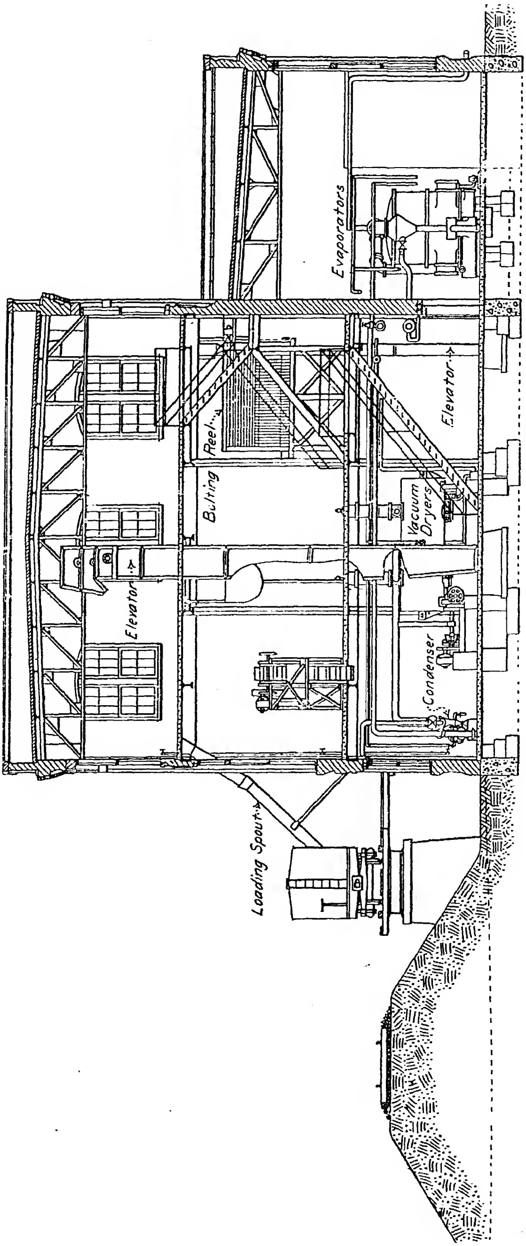

Fig. 104.—City of Columbus (Ohio) Garbage Reduction Works. Section through dryer room.

From personal observation, the author is able to say that the reduction works at Columbus, Ohio are free from those objections which have been the subject of continual complaint in connection with reduction works generally.

The fact that these works are operated without offence is accounted

for by reason of the great attention which Mr Osborn has devoted to those points which some would term unimportant details.

The primary object of a municipality, as the sanitary and health authority, must be the operation of works of this kind without offence: this being accomplished, every effort should be put forth to place the undertaking on a sound financial basis; in short, to be self-supporting, which is all that can reasonably be expected in connection with a sanitary department.

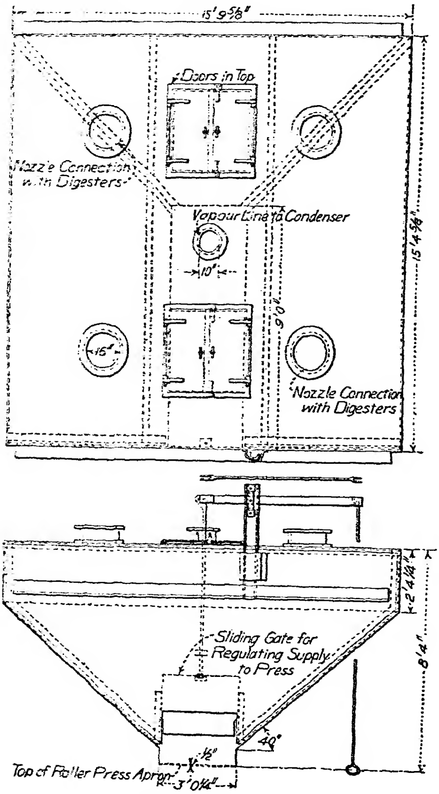

FIG. 105.—City of Columbus (Ohio) Garbage Reduction Works. Receiving tanks.

As already observed, the primary object—indeed the only object—of a company operating a reduction works is to make money. While under municipal ownership money is spent freely in improvements and in eliminating the possibility of nuisance, under the control of a company the period and terms of the agreement offer but little if any incentive to spend any money over and above that which is absolutely necessary for the maintenance and operation of the works; hence such works have too often proved to be a serious nuisance, even to those residing a considerable distance therefrom.

When discussing refuse disposal with Commissioner Briggs, Chief of the Public Health Department of the city of Milwaukee, the Commissioner told the author that, in his opinion, one of the most important future developments would be the combination of destructors with garbage reduction works.

The fact that a considerable quantity of steam is required at a garbage reduction works, and that under the ordinary conditions the coal bill is a very serious item in the operating charges, is all in favour of the combination of a refuse destructor which, while disposing of rubbish or ashes, or both classes of waste, would, in all probability,

furnish the whole of the steam required, not only in the reduction works, but for all purposes in both works.

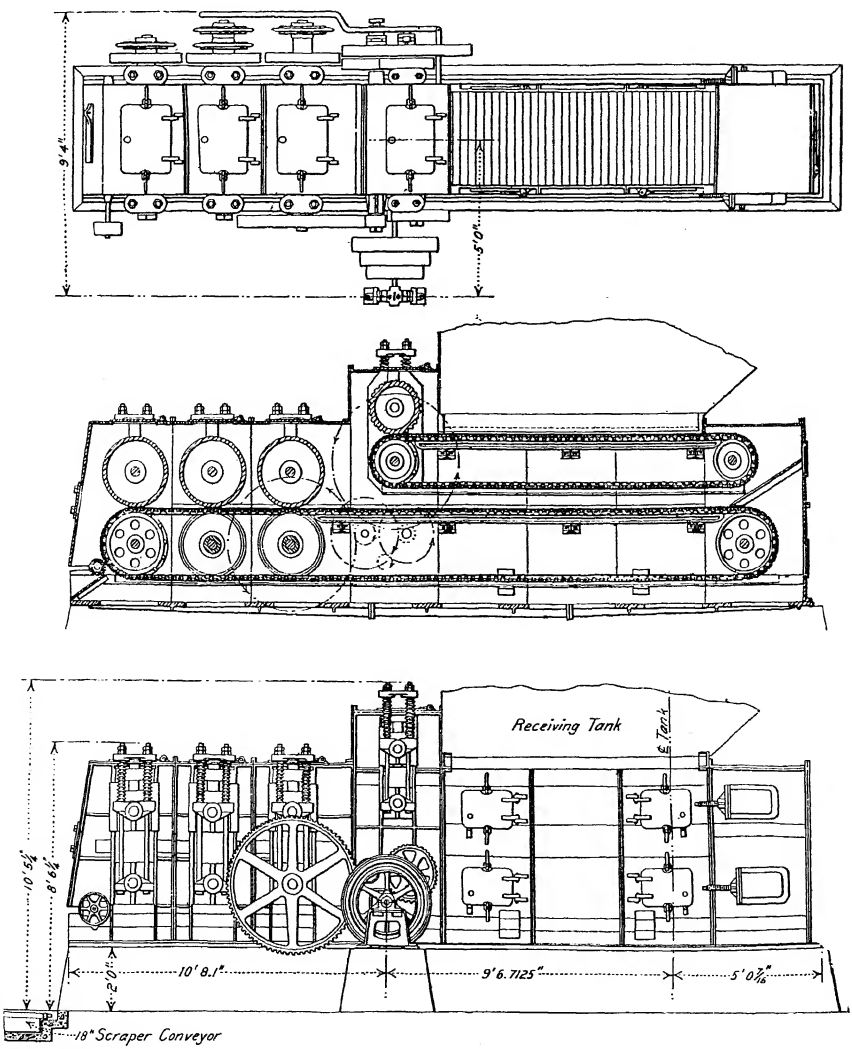

FIG. 106.—City of Columbus (Ohio) Garbage Reduction Works. Roller press.

The author is in cordial agreement with Commissioner Briggs concerning the possibilities of this combination, which offers such obvious advantages.

It is impossible to investigate the refuse-disposal problem in American

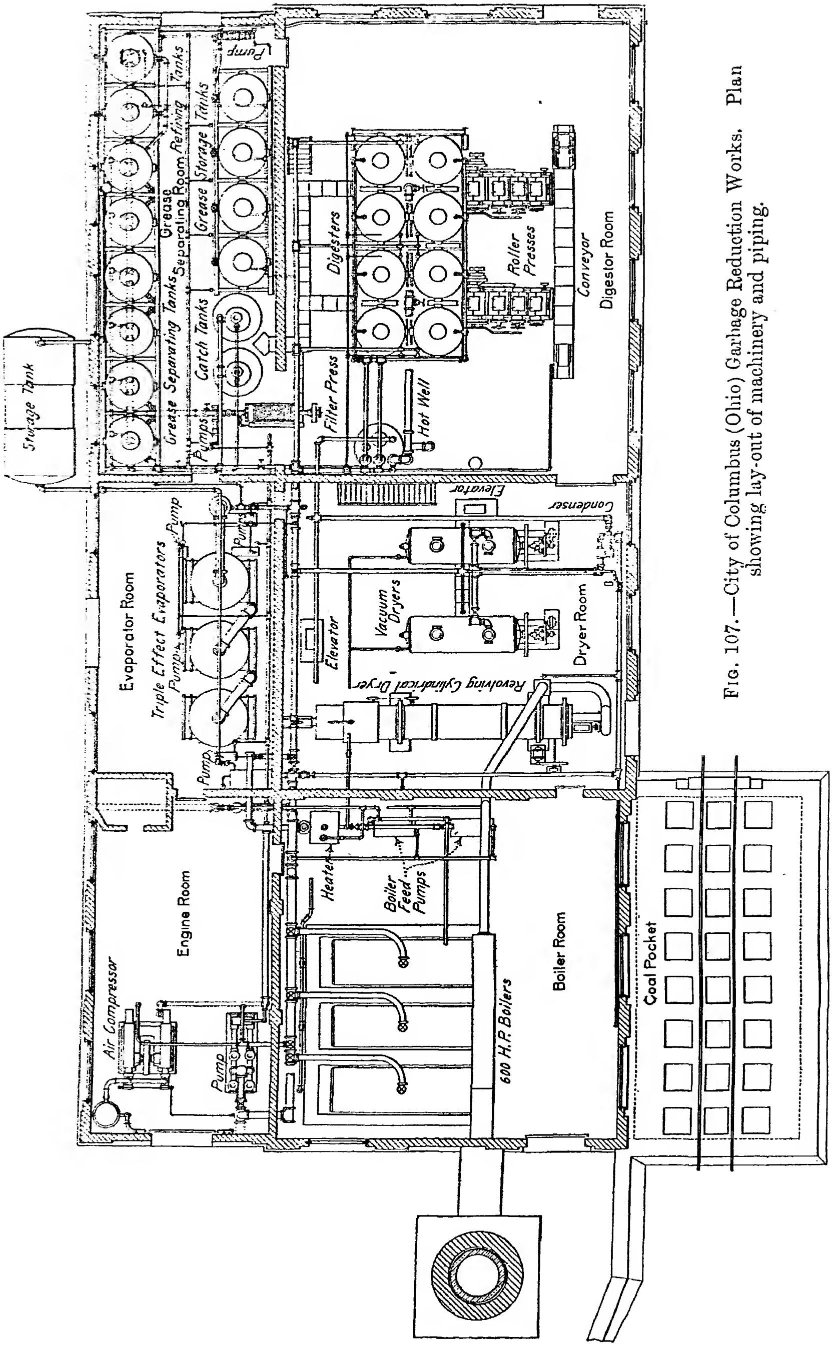

FIG. 107.—City of Columbus (Ohio) Garbage Reduction Works. Plan showing lay-out of machinery and piping.

cities without being vividly impressed with its complex character and extent.

The following figures extracted from the report of the Department of Street Cleaning, New York city, for the year 1909, accounts for the disposition of 3,159,274 cartloads of ashes, rubbish, and garbage collected during that year, the ashes alone exceeding $2\frac{1}{2}$ million cartloads.

Boroughs of Manhattan, The Bronx, and Brooklyn.

At sea and behind bulkhead	$1,741,405\frac{1}{2}$
At Barren Island (garbage)	332,045
At private dumps	$158,343\frac{3}{4}$
At inland „	$185,008\frac{1}{4}$
At incinerators	$23,974\frac{1}{2}$
At 97th Street Dock	57
Capsized	400
By Borough Development Co., Brooklyn	718,040
Total Cartloads	3,159,274

The dumping of rubbish at sea, a source of frequent complaint owing to the defilement of beaches, has been abandoned, and is only likely to be resorted to in the event of a serious strike or other emergency. For some years past considerable quantities of ashes have been removed by scows to Riker's Island and there utilised for reclamation and land filling, which work promises to be exceedingly useful in eventually placing at the disposal of the city upwards of 160 acres of valuable land.

Fig. 108 illustrates the loading of scows at Canal Street dump, New York, for Riker's Island.

The ashes and rubbish collected in Brooklyn are conveyed in specially constructed cars over the track of the Brooklyn Rapid Transit Company, and utilised for land filling, principally on low-lying meadows in the vicinity of Coney Island. In fig. 109 is shown one of the large cars from which ashes are being discharged direct from the steel bins.

The question of disposal by fire has not aroused much interest on the part of the Department of Street Cleaning in New York up to the present. Having in mind that the ashes and garbage disposal methods are organised and that some of the rubbish only remains to be dealt with, the lack of interest in cremation may to some extent be accounted for. As already observed, the ashes are utilised in what would appear to be a profitable manner; the garbage is taken to the Barren Island reduction works, which works have already been described.

There is little doubt that had it not been for the unsatisfactory

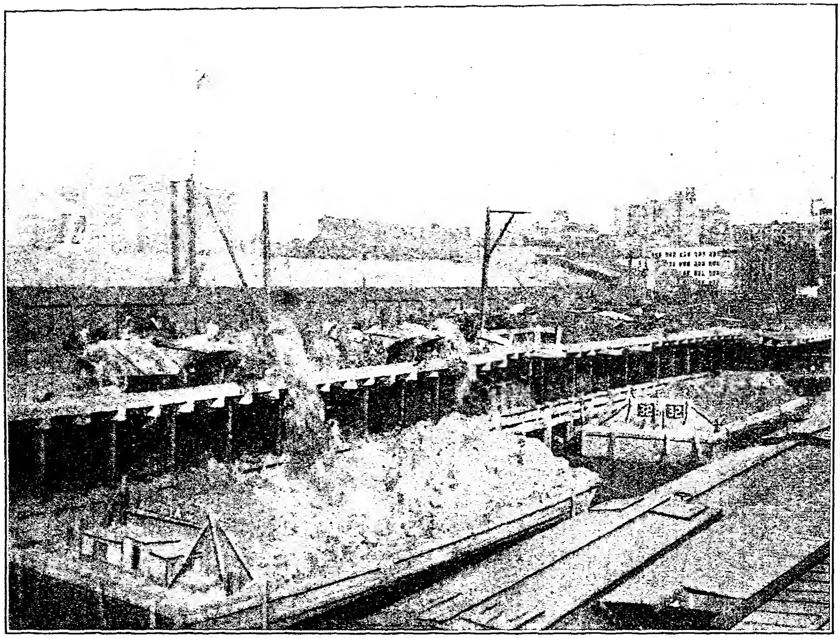

FIG. 108.—Canal Street Dump, New York.

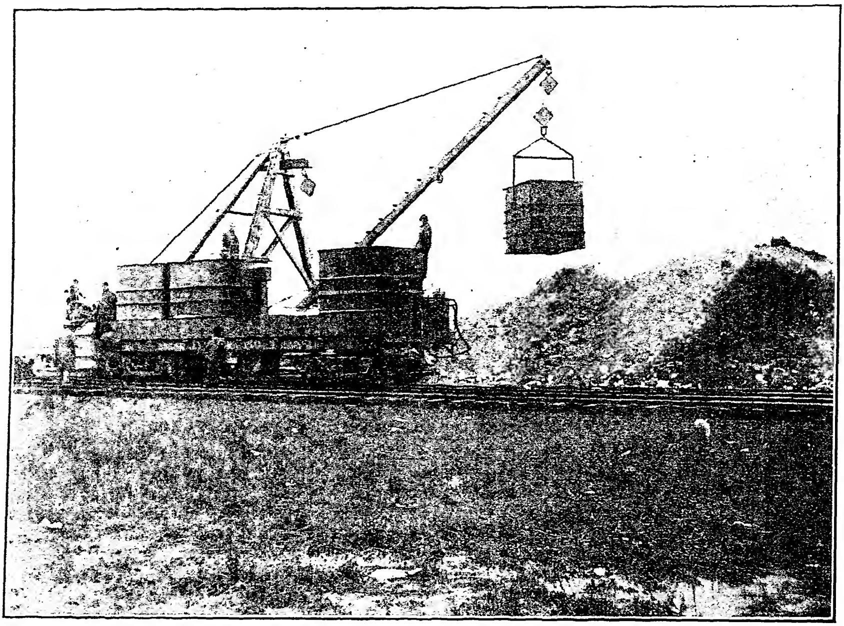

FIG. 109.—Brooklyn (N.Y.), dumping ashes from Steel Bins.

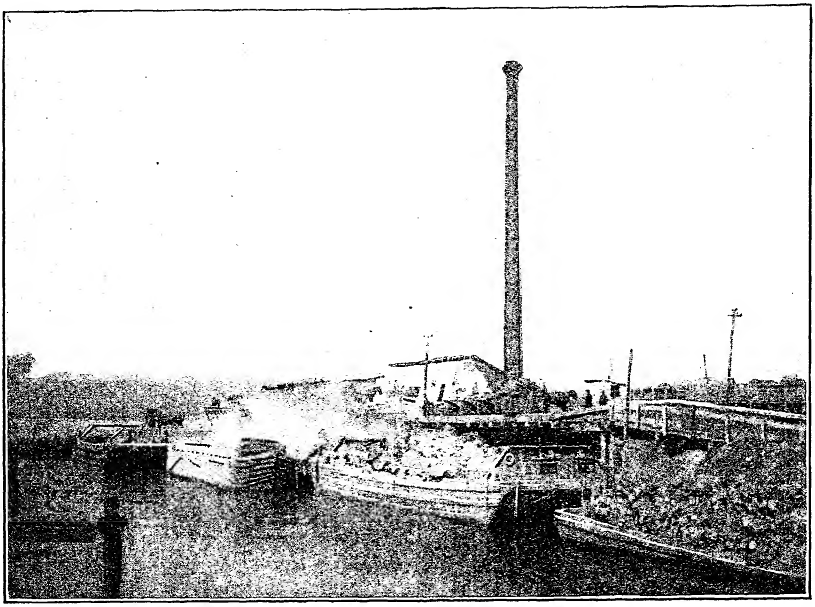

Fig. 110.—Forty-seventh Street Dump, New York.

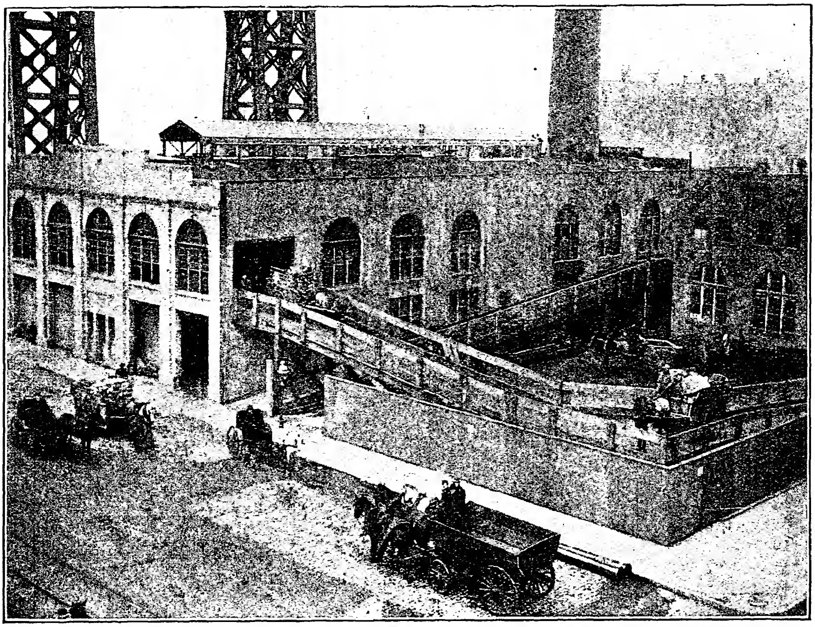

Fig. 111.—Delancy Street Refuse-disposal Station, New York.

results obtained with incinerators of departmental design erected to destroy rubbish, much more would have been done in this direction.

A rubbish destructor, as distinguished from a destructor for dealing with mixed refuse, would seem to the inexperienced to present an easy problem in design. On the contrary, the lighter and more combustible the material, the more difficult is it to design a really satisfactory furnace. Had the Department of Street Cleaning left this problem to the destructor engineer, it is quite certain that cremation would be viewed with more favour at this time.

FIG. 112.—Sorting light Refuse on Scows, Canal Street, New York.

The two incinerators erected in New York are located at 47th Street, and Delancy Street, under Williamsburgh Bridge. These works are illustrated in figs. 110 and 111 respectively.

The composition of light refuse or rubbish is shown in fig. 112, which illustrates the sorting of this material on a scow at a waterside dump in New York.

THE COMPOSITION OF REFUSE.

While it has been known for many years past that the ashes collected in the city of New York during the winter months contain approximately 20 per cent. of recoverable coal, very little data concerning the composition of waste generally has been available.

Coincidently with the ever-increasing interest in sanitary disposal much data has been compiled, more particularly within the past three years, and will be found both interesting and useful to the student and the engineer.

The tables and data herein included have been brought together in this chapter so as to be available in convenient form for easy reference. Table XXXVII. has been compiled by the author from reports prepared by Mr R. H. Thomson, city Engineer of Seattle (Wash.), Mr Rudolph Hering of New York, Mr J. T. Fetherston of Richmond, N.Y., and Mr X. H. Goodnough of Boston, Mass. Fig. 113 very clearly illustrates the position in the city of Boston, where the percentage of ashes collected is exceedingly high.

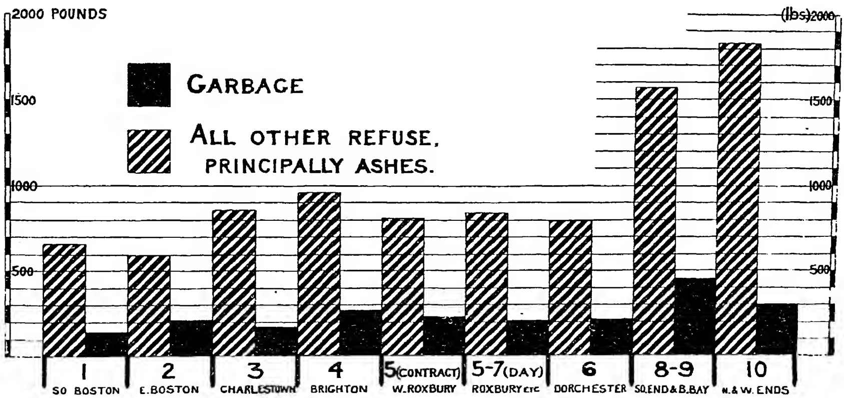

Fig. 113.—Boston (Mass.). Diagram showing relative Weights of Refuse per capita per annum.

Tables XXXVIII. and XXXIX. afford useful information concerning the refuse of San Francisco, Cal., while Tables XL. and XLI. bring together interesting comparative data concerning the refuse of San Francisco and Richmond, N.Y.

In Tables XLII. and XLIII. will be found moisture tests, proximate analyses, and calorific values of components of Clifton district, N.Y., mixed refuse, by Mr J. T. Fetherston.

Chemical analyses by Professor S. F. Peckham of dry composite samples of coal and cinders, garbage and rubbish, as collected in Richmond, N.Y., in 1905–6, are set forth in Table XLVI. Figs. 114 and 115 are diagrams prepared by Mr J. T. Fetherston as the result of exhaustive experiments with the refuse of West New Brighton, N.Y. Fig. 116 illustrates garbage compression tests conducted at the Lederle Laboratories, New York, with a view to determining the amount of

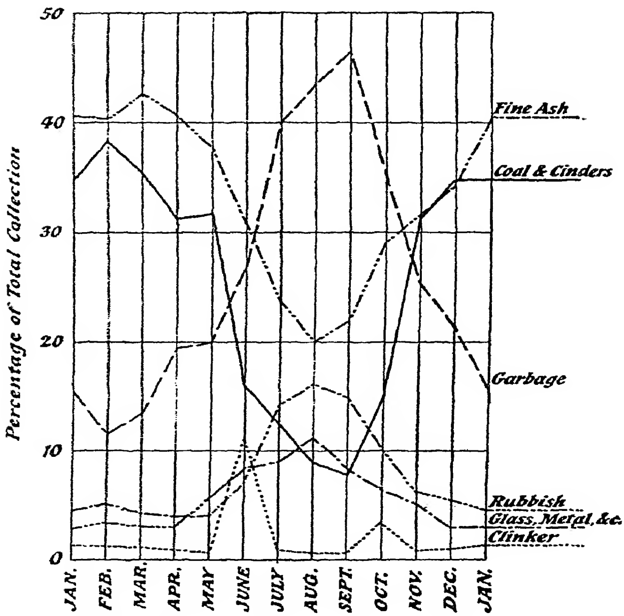

FIG. 114.—West New Brighton (N.Y.). Diagram showing Monthly Variations in Composition of Refuse.

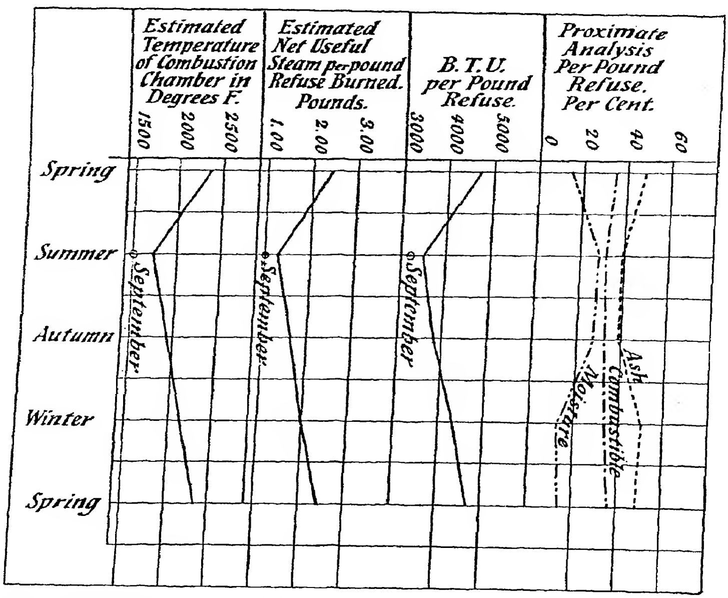

FIG. 115.—West New Brighton (N.Y.). Diagram showing Seasonal Variations in the Quality and Composition of the Refuse.

liquid which could be extracted from the fresh garbage of New York by compression. One cubic yard of garbage was placed in a cylindrical vessel 3 ft. in diameter and 4 ft. deep.

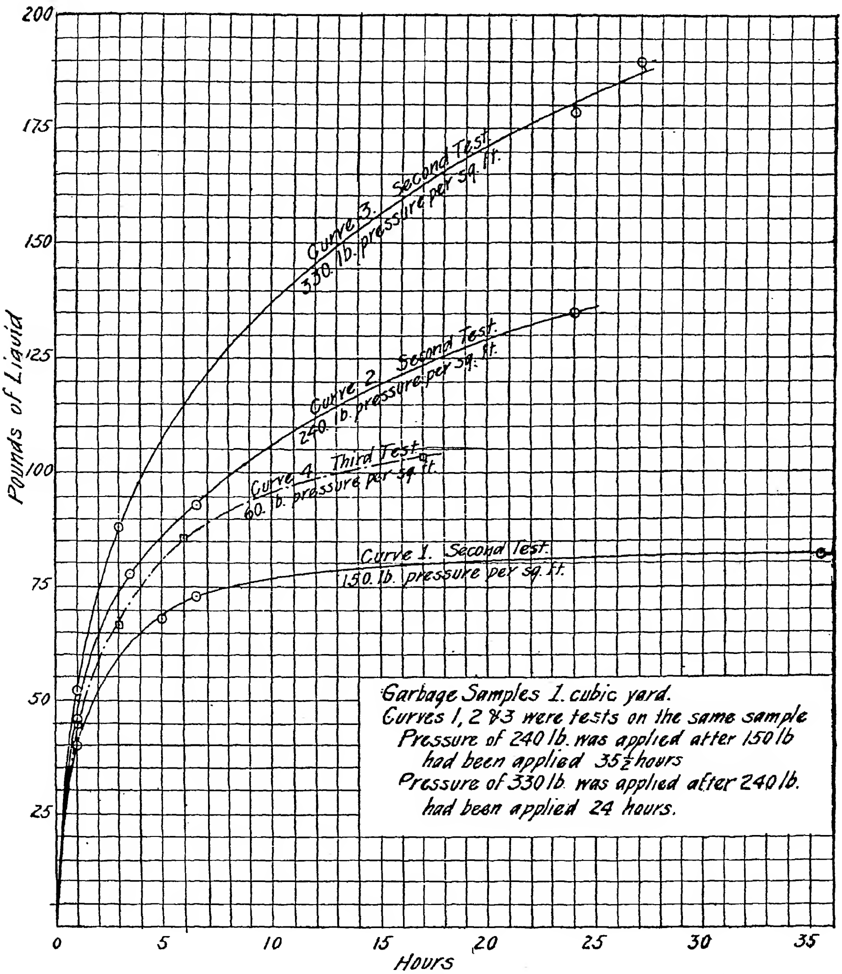

FIG. 116.—Diagram showing results of Pressure Tests for the extraction of Moisture from New York Garbage.

Weights of 438, 1059, 1694, and 2330 pounds, corresponding respectively to 60, 150, 240, and 330 lbs. per sq. ft., were placed on the garbage, and the water drawn off at recorded intervals and measured.

In Tables XLIV. and XLV. very complete details of analyses of New York ashes and rubbish are given.

TABLE XXXVII.—COMPARATIVE TABLE SHOWING VARYING PERCENTAGES OF GARBAGE, RUBBISH, AND ASHES DURING EACH MONTH, IN SEATTLE (WASH.), MILWAUKEE (WIS.), CLIFTON (N.Y.), AND BOSTON (MASS.).

	Garbage, per Cent.				Rubbish, per Cent.				Ashes, per Cent.			
										Clifton, N.Y.		
	Seattle, Wash.	Milwaukee, Wis.	Clifton, N.Y.	Boston.	Seattle, Wash.	Milwaukee, Wis.*	Clifton, N.Y.	Boston.	Seattle, Wash.	Fine Ash.	Coal and Cinders.	Boston.
January	25·1	31·7	20·1	11·9	26·8	65·6	8·0	11·1	44·0	39·5	22·8	75·9
February	30·3	30·3	21·3	11·3	22·8	56·7	7·2	10·2	34·3	38·7	22·6	77·4
March	22·5	36·7	24·7	11·3	23·2	56·7	7·9	10·8	43·5	36·1	21·6	76·7
April	17·6	31	31·7	11·2	24·1	35·0	10·3	11·5	47·2	30·9	15·6	76·1
May	20	38·7	34·7	12·3	22·0	50·0	13·9	12·2	42·0	26·5	13·3	74·1
June	22·2	53·7	41·5	15·0	21·3	41·3	16·1	14·7	37·8	19·1	11·3	68·6
July	17·2	52	47·3	15·6	23·5	34·0	17·1	14·9	29·5	14·2	8·4	68·8
August	7·9	56·7	51·0	16·1	27·9	34·7	16·0	14·6	34·8	14·2	8·0	67·5
September	33·3	51	49·4	16·1	22·5	34·0	15·3	14·7	38·4	13·6	8·5	67·2
October	34·1	44·3	35·5	15·4	12·2	38·0	13·0	14·4	43·7	27·4	13·9	68·6
November	29·4	38	25·1	13·7	15·9	47·3	9·9	13·3	51·4	35·7	18·8	71·6
December	29·3	30·7	22	12·5	14·6	57·0	8·8	11·5	54·5	37·8	21·5	74·8

* From page 361 of the *Transactions of the American Society of Civil Engineers*, vol. lx., 1908.

TABLE XXXVIII.—SHOWING THE WEIGHT AND VOLUME OF REFUSE FROM EACH SECTION OF THE CITY DELIVERED TO THE PLANT OF THE SANITARY REDUCTION WORKS, SAN FRANCISCO, DURING THE NINETEEN WEEKS BEGINNING OCTOBER 11, 1908, AND ENDING FEBRUARY 20, 1909.

Refuse Collected from	Total Refuse.		Ashes.	Garbage.	Rubbish.	Total Refuse.	Unit Weight of Refuse in lbs. per cub. ft.
	Lbs.	Tons.	Cub. Ft.	Cub. Ft.	Cub. Ft.	Cub. Ft.	
Section I.	6,621,113	3,311	18,655	79,986	96,923	195,564	33·8
Section II.	29,268,083	14,634	60,921	337,014	596,903	994,838	29·4
Section III.	52,015,153	26,007	123,013	560,801	1,098,137	1,781,951	29·2
Section IV.	13,048,182	6,524	41,011	156,798	183,960	381,769	34·2
Total	100,952,531	50,476	243,600	1,134,599	1,975,923	3,354,122	30·1

TABLE XXXIX.—SHOWING THE TOTAL QUANTITY OF REFUSE COLLECTED IN THE YEAR 1908, ESTIMATED FROM DATA OBTAINED FROM THE SANITARY REDUCTION WORKS, SAN FRANCISCO, AND SHOWING THE PROBABLE QUANTITIES OF ASHES, GARBAGE, RUBBISH, AND MANURE COLLECTED, AS COMPUTED FROM THE DATA OBTAINED BY INVESTIGATION BY THE BOARD OF PUBLIC WORKS.

	Estimated Average for the Year.	Quantity of Refuse collected in 1908.	
	Tons per Week Day.	Tons.	Cubic Yards.
Ashes	43	13,600	24,000
Garbage . . .	199	63,000	114,000
Rubbish . . .	164	51,900	178,000
Manure	27	8,400	21,000
Total .	433	136,900	337,000

TABLE XL.—COMPARING THE BOROUGH OF RICHMOND, NEW YORK, SEPTEMBER REFUSE, WITH THE SAN FRANCISCO REFUSE AS REGARDS HEATING VALUE AND COMPOSITION

	Unit Weight of Refuse in lbs. per cub. ft.	Percentage of Combustible in Refuse by Weight.	Percentage of Incombustible in Refuse by Weight.	Percentage of Moisture in Refuse by Weight.	Heating Value of the Combustible in Refuse in B.T.U. per lb.	Heating Value of Refuse as collected in B.T.U. per lb.
New York— September *	32·0	30·48	33·69	35·83	10·710	3·265
San Francisco—						
Section I.	33·4	22·0	31·5	46·5	11·040	2·425
Section II.	28·9	26·6	24·3	49·1	10·150	2·709
Section III.	28·4	21·8	26·8	51·4	10 631	2·312
Section IV.	36·3	21·1	32·9	46·0	10·700	2·247
Average, San Francisco .	29·7	22·9	27·2	49·9	10·530	2·410

* Computed from data given in tables on pages 352 and 404 of the *Transactions of the American Society of Civil Engineers*, vol. lx., 1908.

TABLE XLI.—COMPARING THE COMBUSTIBLE MATERIALS IN THE REFUSE COLLECTED FROM VARIOUS SECTIONS OF SAN FRANCISCO WITH THE COMBUSTIBLE MATERIALS IN THE REFUSE COLLECTED IN THE BOROUGH OF RICHMOND, NEW YORK.

	Percentage of Carbon in Refuse by Weight.	Percentage of Hydrogen in Refuse by Weight.	Percentage of Oxygen in Refuse by Weight.	Percentage of Nitrogen in Refuse by Weight.
New York— September*	17·10	2·12	10·00	1·26
San Francisco—				
Section I.†	13·1	1·7	6·7	·5
Section II.	15·2	1·8	9·0	·6
Section III.	13·4	1·6	6·3	·5
Section IV.	13·0	1·4	6·2	·5
Average, San Francisco . .	13·9	1·7	6·8	·5

* Computed from data given in tables on pages 352 and 404 of the *Transactions of the American Society of Civil Engineers*, vol. lx., 1908.

† The above values for San Francisco were obtained from the samples from which the values shown in Table XL. were determined.

TABLE XLIV.—ASHES.

Analyses A, B, and C were made by Messrs Simonds and Wainwright on March 29, 1904.
Sample A was taken from Clinton Street dump, Manhattan.
Sample B was taken from Stanton Street dump, Manhattan.
Sample C was taken from West Forty-seventh Street dump, Manhattan.
Analyses D and E were made by the Lederle Laboratories at the request of the Commission.
Sample D was taken from West Forty-seventh Street dump, Manhattan, on September 23, 1907.
Sample E was taken from East One-Hundred-and-Seventh Street dump, Manhattan, on October 1, 1907.

ANALYSES OF ASHES FROM CITY DUMPS.

	A. Per Cent.	B. Per Cent.	C. Per Cent.	D. Per Cent.	E. Per Cent.
Moisture	1·69	0·80	0·83	0·93	1·20
Volatile combustible matter .	36·12	31·77	35·44	21·71	13·39
Fixed carbon				22·17	20·87
True ash	62·19	67·43	63·73	55·19	64·54
Total .	100·00	100·00	100·00	100·00	100·00
Moisture in original sample .	...	...	...	42·00	22·85
Analyses calculated to original material:—					
Water				42·00	22·85
Volatile combustible matter				12·71	10·45
Fixed carbon				12·98	16·30
True ash				32·31	50·40
Total .				100·00	100·00

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; FROM MECHANICAL ANALYSES.

Garbage.			Rubbish.			Total Moisture % per lb. Mixed Material.
Composition. %	Moisture in 1 lb. %	Total Moisture. %	Composition. %	Moisture in 1 lb. %	Total Moisture. %	
21·2	61·97	13·13	8·0	16·04	1·28	20·60
22·2	55·35	12·29	7·2	19·13	1·38	20·18
28·6	60·71	15·54	7·9	15·03	1·19	23·50
32·7	57·98	18·96	10·3	16·57	1·71	27·96
35·8	53·76	19·24	13·9	15·13	2·10	25·81
42·9	60·94	26·14	16·1	16·97	2·73	32·97
48·6	61·28	29·78	17·1	8·09	1·38	32·97
52·3	56·42	29·51	16·0	10·74	1·72	33·38
50·8	58·04	29·48	15·3	26·23	4·01	38·25
36·5	60·75	22·17	13·0	25·88	3·36	30·39
26·1	57·17	14·92	9·9	18·16	1·80	24·16
23·0	55·96	12·87	8·8	21·84	1·92	22·48
31·1	58·36	20·34	10·8	17·48	2·05	27·72

'OMPONENTS PER POUND MIXED REFUSE.

	Garbage.			Rubbish.					Totals.				
	Fixed Carbon.	Ash.	B.T.U.	Moisture.	Volatile Combustible.	Fixed Carbon.	Ash.	B.T.U.	Moisture.	Volatile Combustible.	Fixed Carbon.	Ash.	B.T.U.
Januai	1·2	0·8	623	1·7	4·4	1·1	0·8	506	23·0	11·8	25·0	40·7	4732
Februs	1·5	1·0	762	1·8	3·8	0·9	0·7	411	22·8	12·3	24·8	40·1	4638
March	1·5	1·1	777	1·6	4·4	1·1	0·8	474	25·8	12·9	23·6	37·7	4485
April	2·0	1·5	1054	2·2	5·7	1·4	1·0	609	30·5	16·2	18·7	34·6	4035
May .	2·5	1·8	1278	2·8	7·8	1·9	1·4	835	28·5	20·1	18·3	33·1	4246
June	2·5	1·8	1293	3·5	8·8	2·2	1·6	949	35·7	20·8	15·5	28·0	3908
July .	2·8	2·0	1447	2·4	10·3	2·6	1·8	1447	36·0	23·6	13·9	26·5	3874
Augus	3·4	2·4	1755	2·6	9·4	2·4	1·6	1013	36·5	25·3	13·9	24·3	4031
Septen	3·1	2·3	1639	4·7	7·4	1·9	1·3	800	41·0	22·2	12·3	24·5	3571
Octobe	2·1	1·5	1101	4·0	6·3	1·6	1·1	680	33·1	17·1	18·0	31·8	3993
Novem	1·7	1·2	862	2·3	5·4	1·3	0·9	574	76·6	14·5	21·8	37·1	4349
Decem	1·5	1·1	777	2·3	4·6	1·1	0·8	488	24·9	13·2	23·7	38·2	4535
:	1·6	1·1	831	2·7	5·7	1·4	1·0	616	30·1	14·5	20·4	35·0	4141

TABLE XLIV.—*contd.*

Analyses F, G, and H were made by Messrs Simonds and Wainwright on February 10, 1904.

Sample F is ash from an open grate burning English Cannel coal, and was taken from a private residence in Manhattan.

Sample G is ash from a stove burning anthracite, size "Stove No. 2," and was taken in Manhattan.

Sample H is ash taken from a hot-air furnace burning anthracite, egg size, and was taken from a private residence in Manhattan.

Analyses J, K, and L were made by the Lederle Laboratories at the request of the Commission.

Sample J was taken from a private residence on East Thirty-eighth Street, Manhattan, on September 23, 1907.

Sample K was taken from an apartment house on October 30, 1907.

Sample L was taken from a hotel on October 30, 1907.

ANALYSES OF HOUSEHOLD ASH.

	F. Per Cent.	G. Per Cent.	H. Per Cent.	J. Per Cent.	K. Per Cent.	L. Per Cent.
Moisture	0·64	0·36	0·06	1·44	0·81	0·62
Volatile combustible matter	} 21·83	8·83	13·44	15·03	3·04	0·87
Fixed carbon				17·37	27·71	31·96
True ash	77·53	90·81	86·50	66·16	68·44	66·55
Total	100·00	100·00	100·00	100·00	100·00	100·00
Moisture in original sample	...	...	...	30·00	27·51	11·62
Analyses calculated to original material :—						
Water				30·00	27·51	11·62
Volatile combustible matter				10·67	2·22	0·78
Fixed carbon				12·34	20·25	28·42
True ash				46·99	50·02	59·18
Total				100·00	100·00	100·00

This Commission communicated with large consumers of coal for steam uses, and some of the replies gave the following results :—

	Combustible Matter.
Reply No. 1, Manhattan	19·70 per cent.
Reply No. 2, Manhattan	23·00 ,,
Reply No. 3, Brooklyn	22·00 ,,

Table XLV.

Rubbish.

Analysis A was made by the Lederle Laboratories at the request of the Commission, on rubbish as delivered at Delancy slip, Manhattan, October 1907.

Analysis B was made by the Lederle Laboratories at the request of the Commission, on rubbish as delivered at the West Forty-seventh Street dump, Manhattan, October 1907.

Analysis C was made by ex-Commissioner Macdonough Craven on New York rubbish.

Analysis D was made by H. de B. Parsons on rubbish at the Delancey slip station, Manhattan, December 1905.

Analysis E was made by F. W. Stearns, of the Department of Street Cleaning, at the Thirtieth Street dump, Manhattan, October 1904.

Analysis F was made by F. W. Stearns, of the Department of Street Cleaning, at the West Forty-seventh Street dump, Manhattan, October 1907.

Mechanical Analyses of Rubbish in Percentage of Weight.

Component Parts.	Percentage of Total Combustion.			Percentage Picked Out as Marketable.		
	A.	B.	C.	D.	E.	F.
Rags	3·70	2·90	15·50	4·60	...	2·78
Rubber	...	...	0·10	...	...	...
Leather	...	...	1·80	...	...	...
Wood	12·50	31·50	1·40	...	7·30	8·91
Metals	6·30	3·70	3·30	0·86	1·30	4·10
Glass	...	1·20	2·90	...	1·40	0·76
Bagging	...	...	...	...	...	0·39
Carpets	..	...	...	...	...	0·57
Shoes	...	...	...	...	...	0·39
Hats	...	...	...	..	...	0·03
Rope and string	...	...	...	...	...	0·23
Paper	39·00	25·90	75·00	25·40	33·30	...
Newspaper	...	...	...	...	...	10·94
Manila	...	...	...	...	...	2·64
Pasteboard	...	...	...	...	...	10·35
Mixed	...	...	...	...	...	6·16
Books	...	...	...	...	...	0·55
Other material	38·50	34·80	...	...	...	...
Total marketable	...	...	...	(30·86)	(43·30)	(48·80)
Total worthless	...	...	...	69·14	56·70	51·20
Total	100·00	100·00	100·00	100·00	100·00	100·00

Average of two chemical analyses of dry rubbish made of material delivered at Delancy Slip Station, December 1905, by D. C. Johnson:—

	Per cent.
Nitrogen	1·00
Hydrogen	5·60
Carbon	45·81
Oxygen	39·01
Ash	8·58
Total	100·00

Average percentage of water in original sample, 11·50 per cent.

TABLE XLV.—*contd.*

Analysis calculated to original material containing 11·50 per cent. water:—

	Per cent.
Water	11·58
Nitrogen	0·89
Hydrogen	4·96
Carbon	40·54
Oxygen	34·52
Ash	7·59
Total	100·00

Determination by D. C. Johnson of the calorific value of dry rubbish delivered at Delancy Slip Station, Manhattan, December 1905:—

	B.T.U.
Sample No. 1, by Mahler Calorimeter	7,810
Sample No. 2, ,, ,,	7,750
Sample No. 3, ,, ,,	7,580
Sample No. 4, from chemical analysis	7,150

TABLE XLVI.

Chemical Analysis of Dry Composite Samples of Coal and Cinders, Garbage and Rubbish, 1905–06.

Constituents.	Coal and Cinders.	Garbage.	Rubbish.
	Per Cent.	Per Cent.	Per Cent.
Carbon	55·77	43·10	42·39
Hydrogen	0·75	6·24	5·96
Nitrogen	0·64	3·70	3·41
Oxygen	2·37	27·74	33·52
Silica	30·01	7·56	6·49
Iron oxide and alumina	8·98	0·41	2·03
Lime	1·21	4·26	2·26
Magnesia	Trace	0·28	0·57
Phosphoric acid	None	1·47	0·10
Carbonic acid	None	0·59	1·49
Lead	Trace	0·20	0·52
Tin	Trace Sulphides	...	Trace
Alkalis and undetermined	0·27	4·45	1·21

Calorific Values in British Thermal Units.

Calculated from above analyses	8,382	7,970	7,250
Average of calorimeter determinations	8,510	8,351	7,251

During the next few years much progress will be made both in America and Canada in final and sanitary refuse disposal. At the present time the difficulty of finding a profitable use for the steam generated tends to operate to some extent against the more extensive adoption of destructors of British types.

There are distinct signs that this is only a passing difficulty, and that ways and means for complete utilisation of the steam will be found. The present difficulty is due to the fact that the idea of municipal

ownership of the public utilities has not yet caught the civic fancy to any considerable extent. There is, however, but little doubt that future municipal administration in America will follow closely upon the best British lines. Franchises have limits, and the granting of concessions is by no means as popular now as was the case a few years ago. There is an increasing demand for public control, and this must and will lead to the acquisition of the public utilities to be operated for the benefit of the people.

While it is very desirable that wherever possible the power available from refuse should be fully utilised with a view to avoiding waste and securing a definite revenue to set against and reduce the capital and standing charges, yet it must be observed that, as a destructor pure and simple, the British furnace is in every respect vastly superior to any American furnace yet devised.

This being so, then there should be a future for destructors which are not designed or equipped for the production of more steam than can be utilised in connection with the works. Such destructors will in all probability cost more than American furnaces, but the important points to be observed are (1) that American furnaces have an unsatisfactory record covering many years; (2) that it is exceedingly difficult, if not impossible, to operate most furnaces of American design without nuisance; (3) that they are costly to operate and generally expensive to maintain, whereas British destructors can be operated with an absolute immunity from nuisance; they are designed as the result of a very long and extensive experience, they are of proved merit, can be operated cheaply, and cost but little for maintenance. In short, they are entirely free from the many objections which have been urged against American furnaces, and are being operated with satisfaction in every civilised country.

In the past the complaints concerning the unsatisfactory manner in which tenders have been invited and adjudicated upon have been frequent and well-founded. It has been urged that the firm whose tender was lowest and whose guarantees were highest was invariably successful in securing the contract. It has been contended that no credit has been given for an established reputation or good design, that every encouragement has been given to those who have had no experience, and who have been prepared to incur the most serious risks; further, that the whole system or lack of system in the comparison of schemes and tenders favoured those who had no intention of using good materials, or in any sense giving value for money.

With a view to initiating a definite basis for the comparison of

tenders on certain clearly defined lines, a system of comparison was introduced some four years since, which may be briefly described as follows:—

Tenders are invited for a destructor and certain accessories to a specification. In addition to quoting a lump sum price for furnishing and erecting the complete destructor installation, those tendering are required to guarantee the cost per ton for destruction in accordance with the test requirements, and for the guidance of those tendering the following or similar information is embodied in the specification:—

Award of Contract.—"The bids will be compared, and the contract awarded to the *lowest* responsible bidder upon an annual expense basis determined as follows:—

"To 10% (ten per cent.) of the total cost of the installation, including building, chimney, destructor, and appurtenances, shall be added 12,000[1] times the guaranteed cost of supervision and labour per ton of material incinerated, according to the test requirements, the sum of the above two items being assumed to represent the value of the plant to the city.

"In assuming the total cost of the installation, (*a*) the chimney shall be assumed to cost ; (*b*) the building shall be figured at cents per cubic foot of content, depending upon the spacing and area required by the destructor portion of the work, to which shall be added (*c*) the bid or estimate for the construction of the destructor and appurtenances. 10% (ten per cent.) of the foregoing three items, *a*, *b*, and *c*, shall be assumed to represent the annual incurred fixed charges.

"In determining the operating costs of supervision and labour, 12,000 tons of refuse per year shall be assumed as the amount which will be incinerated.

"Supervision shall be figured at $ per day of 8 hours, and labour at $ per day of 8 hours; a licensed steam engineer shall have charge of the boilers, engines, and power appliances. He may be called upon to assist in the operation of the destructor, in so far as his other duties permit, but he shall not be allowed to help in handling the refuse before it is incinerated.

"Furnace men or clinker men shall perform any of the duties required in the operation of the plant except those in connection with the boilers, engines, or power appliances, which properly belong to the licensed engineer.

"The rates of wages specified for supervision—(a licensed engineer at cents per hour) and labour (furnace men or clinker men at cents per hour), with the limitations of duties already detailed—shall be used as

[1] This will, of course, vary according to the weight of refuse to be disposed of per annum.

the basis by the contractors in arriving at the maximum guaranteed cost of incinerating refuse, in accordance with the test requirements noted in the specification, but no employee shall be permitted to work more than 8 hours in any day."

The following summary of bids received and compared on the above basis is of interest:—

BUREAU OF STREET CLEANING.

BOROUGH OF .

Summary of bids received for the construction of the furnaces, steam boilers, and appurtenances of the destructor, Borough of

BID OR ESTIMATE.

	No. 1.	No. 2.
Lump sum bid price for construction . .	$50,350.00	$67,867.00
Guaranteed cost of incineration per ton .	0.70	0.50
Basis of award—value of plant to city on annual operating basis.		
Investment Charges:—		
Cost of destructor as per bid . . .	$50,350.00	$67,867.00
„ „ chimney (estimated by city) . .	4,000.00	4,000.00
„ „ building „ „ „		
No. 1, 254,006 cubic feet at 0.20 . . .	50,801.25	
No. 2, 176,764 „ „ at 0.20 . . .		34,152.80
Totals .	$105,151.25	$106,019.80
Annual Costs:—		
10% of total investment charges . . .	$10,515.12	$10,601.98
Incineration of[1] 12,000 tons at 0.70 . .	8,400.00	
„ „ „ „ at 0.50 . .		6,000.00
Totals .	$18,915.12	$16,601.98
Gross costs per ton .	1.57	1.38

Low bidder annual basis as per contract No. 2 by $2,314.14

At first sight this method of comparing tenders would appear to have much to recommend it; indeed, it is put forward by some engineers as the final word in so far as a fair and reasonable basis for the comparison of tenders is concerned. Careful consideration, however, will show that it is open to some serious objections.

It will be observed that the engineer, having fixed the price per

[1] Estimated annual tonnage as per contract information and terms.

cubic foot in connection with the buildings, by this action makes it possible for those tendering who submit plans for the smallest buildings to secure an advantage in price over others who tender for a lofty and spacious building; in fact, the very type of building which is desirable for the purpose.

Further, this method of comparison, for the same reason, does not encourage the most serious attention to the design and lay-out of the plant; there is every inducement to save space.

Those who are in a position to offer an installation which materially reduces the cost of labour are placed at an advantage, and this may, and doubtless will, have the effect of encouraging the introduction of untried and experimental mechanical apparatus.

Again, realising that the guaranteed labour cost is an important factor in deciding the contract, there is every inducement held out for the submission of those impossible guarantees which have so often been complained of in connection with American furnace-makers.

In connection with some specifications similarly drafted, a credit value is assumed for the steam, thus encouraging a high guaranteed evaporation. This factor, together with the labour cost and the size of building, introduce elements of a most unsatisfactory nature, especially when it is remembered that the contract is to be awarded to the lowest bidder.

The author is of opinion that the whole system of comparing tenders and schemes upon an equitable basis has yet to be settled, and that no system can be deemed satisfactory or final which has the effect of encouraging speculation, and which fails to ensure the best bargain for the purchaser.

While criticising the method of comparison of tenders and schemes which is favoured by some few engineers in the United States, the author does not suggest that the British method is the best. As a matter of fact, there is no fixed method in Great Britain, and the lack of systematic or methodical comparison is most unfortunate.

In spite of the stock warning that the lowest or any tender will not necessarily be accepted, the fact remains that the lowest tender is usually favoured. It is true that this course is often justified, but, as a general principle, it may be observed that the lowest tender for a refuse destructor should never be accepted without the closest scrutiny of both the tender and the scheme.

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